Lower Echo Lake
Watershed Management Plan

FINAL REPORT

August 2004

Presented to:

County of Union
Department of Parks and Recreation

Prepared by:

F. X. Browne, Inc.
Lansdale, Pennsylvania

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Table of Contents

List of Appendices

List of Tables

List of Figures

Acknowledgments

Lower Echo Lake was one of eleven lakes and ponds investigated as part of the of Union County Eleven Lakes Phase I Diagnostic-Feasibility Study. The Union County Eleven Lakes Phase I Study was funded entirely by the County of Union. Appreciation is extended to all members of the Board of Chosen Freeholders for their dedication and commitment towards preserving the water quality of county-owned lakes.

Thanks is extended to all County employees who assisted in this study. Special gratitude is extended to Mr. Daniel J. Bernier for his invaluable perspective on all eleven study lakes and their surrounding watersheds and his diligent assistance throughout this study.

Executive Summary

Overview

Lower Echo Lake is a 5.3-acre impoundment located in Echo Lake Park in the municipalities of Westfield and Mountainside. The Union County Park Commission created the lake in 1929. Amenities at Echo Lake Park include athletic fields, boating, fishing, ice skating, sledding, picnicking, and a playground.

Several problems are common to the county's waterways including degraded lake water quality, sedimentation, eroding shorelines, proliferation of nuisance weed growth and waterfowl, and inadequate public accessibility. Union County established a team to study and make recommendations for improvement to the County's waterbodies, including 30 lakes, ponds, and lagoons within the County park system, as well as three major rivers and their tributaries. Out of the 30 lakes, the Waterways Team prioritized the top twelve lakes in need of attention. Of the 12 priority lakes, Lower Echo Lake was given a high priority rating of # 9. The lake is in danger of losing a variety of uses due to excessive siltation, algae blooms and an overabundance of aquatic plants and waterfowl. Siltation has been a historic problem.

Union County commissioned F. X. Browne, Inc. to perform a Phase I Diagnostic-Feasibility Study of Lower Echo Lake. The Diagnostic-Feasibility Study was conducted in two stages. The diagnostic portion of the study was conducted to determine current water quality conditions, identify existing problems, and determine the pollutant sources that are responsible for the observed problems. The feasibility aspect of the study evaluated a variety of lake and watershed management alternatives based on the results of the diagnostic study. The product of this study is a Diagnostic Feasibility Report that provides a recommended management plan for the restoration of Lower Echo Lake.

Conclusions

As part of the Lower Echo Lake Phase I Study, a lake water quality monitoring program was conducted from May through August, 1996. Conclusions of the study are based on the diagnostic portion of the project.

Water Quality

- During the summer months, Lower Echo Lake is thermally stratified. Dissolved oxygen levels become depleted in the bottom waters of the lake and may have an adverse impact on the aquatic biota. Anoxic (zero oxygen) conditions in the bottom waters of the lake can cause phosphorus to be released from the sediments into the water column, becoming available for algal growth.

- The "limiting" nutrient in Lower Echo Lake that causes the excessive algae and aquatic weed growth appears to be both nitrogen and phosphorus.

- The average total phosphorus concentration in Lower Echo Lake was 0.390 milligrams per liter (mg/L); a lake with a total phosphorus concentration of 0.03 mg/L or greater is considered eutrophic. The average Secchi disk transparency measurement was 0.94 meters (3.1 feet); a lake with a Secchi disk transparency measurement of less than 2.0 meters (6.6 feet) is considered eutrophic. The average chlorophyll a concentration in the lake was 88.7 micrograms per liter (Fg/L); a lake with a chlorophyll a concentration of 10 Fg/L or greater is considered eutrophic. Based on these parameters, Lower Echo Lake is classified as a highly productive or hyper-eutrophic lake.

- Lower Echo Lake has a relatively fast flushing rate. The estimated detention time of the lake is 4.7 days.

Bathymetry and Sediment Chemistry

- The average water depth in Lower Echo Lake is 4.28 feet. The maximum water depth is 9.5 feet.

- Lower Echo Lake contains approximately 19,700 cubic yards of unconsolidated sediments. The average sediment thickness in the lake is 2.95 feet, and the maximum sediment thickness in the lake is 5.50 feet.

- Sediments in Lower Echo Lake contain benzo(a)pyrene in concentrations that exceed the acceptable level for residential and non-residential sediment disposal. Sediment levels of benzo(a)anthracene, benzo(a)pyrene, and indeno(1,2,3-cd)pyrene exceed the acceptable level for residential sediment disposal.

Macrophytes

- During the summer months, the density of macrophytes (aquatic plants) in Lower Echo Lake is excessive. The most dominant aquatic plants are Spattordock (*Nuphar Sp.*), Coontail (*Ceratophyllum demersum*), and Slender Pondweed (*Potamogeton Sp.*).

Watershed Characteristics

- The ratio of the watershed area to lake surface area is 463:1 which is relatively large. Implementing watershed management practices may have a positive impact on the water quality in Lower Echo Lake, although in-lake management will likely be necessary as well.

- The most dominant land use within the watershed area is medium density residential. Most commercial area is located adjacent to Route 22. Forested land is located in the northeastern portion of the watershed.

! Most of the land immediately adjacent to Lower Echo Lake is forested parkland and grassed fields. The southern shore of the lake is steep and forested, and a golf course is located at the top of this steep slope.

Recommendations

Based on the diagnostic portion of the Lower Echo Lake Phase I Study, the following in-lake and watershed management recommendations were developed as part of a Comprehensive Lake and Watershed Management Plan for Lower Echo Lake.

The recommendations provided in this lake and watershed management plan will help the municipalities to comply with the new EPA Stormwater Phase II Final Rule. Both Westfield and Mountainside were required to submit an application to the NJDEP by March 10, 2003 to be included in the General Phase II Stormwater Permit. The Townships are now required to implement the following minimum control measures to reduce nonpoint source pollutants from stormwater runoff:

1. Public education and outreach
2. Public participation and involvement
3. Illicit discharge detection and elimination
4. Construction site runoff control
5. Post-construction runoff control
6. Pollution prevention and good housekeeping

The recommendations in this report cover most of these requirements including a well run public education program, storm sewer stenciling, identification of potential BMP retrofit areas to improve stormwater quality, and a more effective street sweeping program.

In-Lake Recommendations

1. Dredge unconsolidated sediments and increase the lake depth,
2. Add alum to the lake to reduce phosphorus in the water column, reduce algae, and seal phosphorus in the lake sediments, and
3. Stock the lake with fish.

Watershed Management Recommendations

1. Perform detailed watershed investigations to identify potential stormwater retrofit possibilities in the watershed,
2. Stabilize the lake shoreline,
3. Stabilize streambanks,
4. Control waterfowl around the lake,
5. Implement urban stormwater management program,
6. Encourage environmentally-friendly homeowner practices,
7. Restore riparian corridors
8. Encourage golf courses in the watershed to use environmentally-friendly management practices
9. Encourage better education and stronger enforcement of erosion and sedimentation measures in the watershed,
10. Develop and implement a public education program,
11. Implement a continued water quality monitoring program, and
12. Develop long-term institutional approaches to protect and enhance the water quality in Lower Echo Lake.

Each of the above in-lake and watershed management recommendations are described in more detail in the following sections.

Dredging

! Lower Echo Lake contains 19,700 cubic yards of unconsolidated sediment that should be removed by dredging. Sediments in Lower Echo Lake are contaminated with several types of metals and semi-volatile compounds. Therefore, the sediment must be disposed of in an approved disposal site.

! Potential disposal areas for contaminated sediments include hazardous waste landfills and available non-residential land. County-owned parkland may be acceptable for sediment disposal, but site remediation techniques such as capping of the sediments may be required. The DEP has indicated that they will consider disposal sites for contaminated sediments on a case by case basis. Currently, DEP has no specific guidelines for the disposal of contaminated sediments.

! A dredging feasibility study should be performed before detailed dredging design and permitting begins. The main work elements of the dredging feasibility study should include the following:

1. Attend a pre-application meeting with the DEP to discuss the project, to determine what permits will be required for this specific project, and to discuss potential disposal areas. A pre-application meeting is required by the DEP for dredging projects.

2. Identify a suitable disposal area for the contaminated sediments. Suitable areas may include non-residential properties, including County property, or hazardous waste landfills.

3. Perform an evaluation of beneficial dredged sediment reuse and reclamation of the contaminated sediments

4. Prepare a dredging feasibility report for submission to Union County. Based on information provided in this report, the County can determine if dredging Lower Echo Lake is feasible.

Lake Aeration

! Lake aeration in not recommended at the present time. If lake dredging occurs, lake aeration should be reevaluated to determine if dissolved oxygen levels in the lake still remain low.

Alum Treatment

! Alum treatment may be a feasible restoration option for Lower Echo Lake. Alum is added to the water where it combines with the phosphorus in the water column and settles to the bottom of the pond and “seals” the bottom sediments. Therefore, the phosphorus in the water column is significantly reduced, algal populations are reduced, and phosphorus is sealed in the sediments and is not available for algal growth. This option could be implemented even if dredging were not completed.

Fish Stocking

! Fish stocking is recommended only after in-lake and watershed management practices have been implemented and a suitable fish species diversity study has been completed. The purpose of the fish species diversity study is to ensure optimum survival rates for the introduced fish.

Watershed Investigations

As part of this study, limited watershed investigations were conducted to identify specific nonpoint source pollution problem areas. A more comprehensive study is necessary in order to locate specific problem areas within the large watershed of Lower Echo Lake.

The following steps should be taken to complete a more detailed watershed investigation:

1. Identify specific nonpoint source problem areas. Areas to be investigated should include, but not be limited to, streambanks, culverts, roadways, roadway stream crossings, storm drainage pipes, parking lots, and areas of excessive stormwater runoff.

2. Once problem areas have been identified, they should be prioritized.

3. The problem areas should be analyzed in order of priority for possible retrofit controls, or best management practices (BMPs). Possible retrofit controls may include stormceptor systems, sand filters, bioretention systems, erosion control, stormwater diversion, and modification of fertilization and mowing procedures.

Shoreline Stabilization

! Severely eroded areas along the lake shoreline should be stabilized using a combination of vegetative and structural methods.

Streambank Stabilization

! Streambank erosion downstream of the Lower Echo Lake Dam should be stabilized with a combination of vegetative and structural methods.

! Riparian buffer areas both along the streams and the lake appear to be adequate. These areas should be enhanced, if possible, to ensure wildlife habitat and to provide shading of the water to keep water temperatures low.

Waterfowl Control

! Canada geese populations at Lower Echo Lake are excessive and should be controlled. Geese droppings are a significant and direct source of phosphorus, nitrogen, and bacteria to Lower Echo Lake.

! Geese populations should be controlled. Potential methods for geese control include landscaping, egg inactivation, chemical deterrents, culling during summer molt, scare tactics and geese removal.

! Park visitors should be discouraged from feeding the geese and other waterfowl. Signs should be posted at strategic locations in the park to inform people about not feeding the waterfowl.

! An ordinance to prohibit feeding of waterfowl is recommended. The ordinance should include provisions for enforcement.

Urban Stormwater Management

! Union County and the municipalities of Westfield and Mountainside should evaluate street sweeping schedules. Increased street sweeping is recommended, especially in the spring and summer months.

! Stormwater catch basins should be cleaned after major storm events or at least once every three months. Cooperation between Union County, the local municipalities, and the New Jersey Department of Transportation is recommended for this task.

! Although most of the watershed is developed, every opportunity to improve stormwater quality should be taken. For example, if a commercial establishment changes ownership, and the new owner needs approvals from the local municipality, local ordinances should be in place to require improving stormwater runoff quality from the site before approvals are granted. This approach is being successfully used in Washington D.C. Possible stormwater quality treatment systems that could be installed on a developed property include sand filters, peat filters, or bioretention systems. The purpose of these systems is to treat stormwater runoff from roads and parking lots. These systems are installed to treat the first 0.5 inches of stormwater runoff, which is called the "first flush" and typically contains the highest concentration of pollutants from a storm event.

! Existing homeowners and business owners should be encouraged to direct roof runoff to dry pits or rain barrels to reduce the amount of stormwater that enters the storm sewer system. Using a rain barrel or cistern gives the homeowner the advantage of water use reduction by storing rain water for watering gardens or lawns during dry periods.

Homeowner Practices

Homeowner practices should be implemented as part of the public education program described in the following section.

- Lawn fertilizer can be a significant source of nutrients to lakes and ponds, especially in suburban areas where nice green lawns are desirable. A fact sheet on the importance of proper lawn fertilization should be prepared and distributed to homeowners in the watershed. This task could be facilitated through the public education program described below or by an “extra” in the local newspaper. Fact sheets should be posted at the park and possibly at local businesses.

- Homeowners should be encouraged to maintain appropriate vegetation on their property to control runoff.

- Leaf management is also important in reducing nonpoint source pollution in a developed watershed. The existing leaf management program should be evaluated to determine if there are ways to improve the program so that leaves do not end up in the street for a long period of time. If leaves are left in the street too long, nutrients leach from the leaves and are carried into the storm sewers and eventually into the lake with stormwater runoff. Encouraging or requiring homeowners to bag leaves in biodegradable bags is one possibility for improving the leaf management program.

- Homeowners should be informed that if they dump household chemicals and other substances into storm sewers, these substances will end up in the lake. Storm inlets should be stenciled to educate homeowners that anything that goes down the storm sewer eventually drains to the lake.

- Homeowners should be encouraged to wash cars and trucks on grassy areas, if possible. This practice will reduce the amount of phosphorus and detergents that run down the driveway, into a nearby storm sewer, and eventually into Lower Echo Lake. Another alternative is to use a commercial carwash.

Riparian Corridor Management

- Two tributaries enter Upper Echo Lake, which is upstream of Lower Echo Lake. A large portion of these tributaries are piped, underground systems. However, there are sections of the tributaries that are open, natural channels. These stream corridor areas should be preserved. Since these sections of the streams are located within the Upper Echo Lake Park, Union County should maintain the stream corridors in their present condition. Eroded areas of the streambanks should be stabilized as described above. A 50- to 75-foot buffer should be maintained along the entire stream channel. Willows and other trees should be planted along the smaller inlet stream to stabilize the soil, intercept and treat stormwater runoff, modify stream temperature, and provide valuable habitat for wildlife.

Golf Course Management

! Golf courses within the Lower Echo Lake watershed should be encouraged to minimize the use of fertilizers by turf monitoring and proper timing, water greens only when necessary as a means to reduce fertilizer usage, and implement stormwater management facilities such as constructed wetlands and bioretention strips to reduce fertilizer runoff into nearby water bodies. In addition, a three to five foot unmowed buffer strip along lakeshores and streambanks should be maintained to ensure proper erosion control and to filter runoff. Becoming involved with the Audubon Cooperative Sanctuary Program is an excellent way for a golf course to show the community its commitment to protecting the local environment.

Site Development Erosion and Sediment Pollution Control

! Any earth disturbances greater than one acre require a National Pollution Discharge Elimination System permit from the New Jersey Department of Environmental Protection. Enforcement of erosion and sedimentation control at smaller sites is difficult due to the unsure timing of the actual earthmoving and the general lack of project information. However, erosion and sedimentation pollution control plans are just as important and should be enforced.

Public Education Program

Union County is continuing to develop and implement an environmental education program throughout the County. The County's environmental education program should be integrated into the Lower Echo Lake watershed project. The environmental education program for Lower Echo Lake should include the following elements:

1. Develop and distribute a nonpoint source brochure,
2. Develop a watershed management curriculum for presentation to local schools,
3. Develop and install one or more kiosks at Lower Echo Park Lake,
4. Write fact sheets on watershed management for distribution at the kiosk and at park events, and
5. Include staffing for conducting watershed management education programs at the satellite operation of Trailside Nature and Science Center being developed by the County in Warinanco Park.

Water Quality Monitoring Program

- A limited water quality monitoring program should be implemented, after dredging has been completed, to document water quality improvements. Yearly monitoring of selected parameters (i.e. total phosphorus, total nitrogen, chlorophyll a, and Secchi disk depth) should be conducted to document water quality changes in the lake.

Institutional Approaches

- The Union County Waterways Team should work closely with Township officials to improve the water quality in Lower Echo Lake and to implement this Watershed Management Plan.

- The Union County Waterways Team and local municipalities should evaluate existing subdivision ordinances, erosion and sedimentation control ordinances, stormwater management ordinances, and other existing ordinances to look for way to strengthen these ordinances to protect the water quality in Lower Echo Lake.

1.0 Project Description

1.1 Introduction

In the early 1920's, Union County Sheriff James E. Warner had a dream to protect the Rahway River from over development and pollution. Echo Lake Park was established in 1925 as a part of the Union County Park Commission's vision to see the Sheriff's dream become a reality. Echo Lake Park and 26 other parks that today comprise 5,000 acres of park land in Union County were the result of years of hard work and political activism on the part of Union County Park Commissioners and dedicated volunteers. The land around Echo Lake was chosen to become a park because of its centralized location, its easy accessibility, and its wooded valley that kept its picturesque waters hidden from the nearby urban centers. Echo Lake Park is part of a greenway connecting the Rahway River and the Watchung Reservation.

Lower Echo Lake was previously an old mill pond, known simply as Echo Lake, and was used primarily for fishing and swimming. The land around the lake was developed as a park in 1925, and an attractive kiosk shelter with a waterwheel was built at the site of the old dam at that time. The waterwheel was restored in 1963. Upper Echo Lake was created in 1929 by the addition of a dam that flooded the upper valley. The two lakes are connected by a wildlife sanctuary situated around a small stream. Lower Echo Lake is enjoyed today, as it was in the early days, for fishing, boating, picnicking, swimming and ice skating.

1.2 Background

In 1995, the County of Union established a "Waterways Team" which had the primary objective of developing a strategic plan to improve the County's waterways. The Waterways Team, consisting of ten County staff employees and a municipal watershed inspector, initially set its sights on dealing with 30 or more lakes, ponds, and lagoons that are County-owned and located in the County's vast park system. More recently, the team has also begun to examine problems along the County's rivers and streams, most notably the Rahway River, to which Lower Echo Lake drains.

The most common lake problems noted by the Waterways Team were degraded water quality, accumulation of litter, debris, and sediments, eroding shorelines, proliferation of nuisance weed growth, overabundance of waterfowl, degraded dam structures, and poor accessibility for the public.

The Waterways Team has determined the 12 most critical lakes and ponds in the Union County Park System. The team used a priority ranking system to evaluate the overall degradation of County-owned lakes. One of these lakes, Lake Surprise, was studied by F. X. Browne, Inc. (1995). The Lake Surprise Phase I Diagnostic-Feasibility Study was conducted in accordance with CFR, Part 35, Subpart H entitled "Cooperative Agreements for Protecting and Restoring Publicly Owned Freshwater Lakes" which pertains to the federal

Clean Lakes Program. Based on qualifications and the success of the Lake Surprise Phase I Study, Union County retained F. X. Browne, Inc. to implement the Lake Surprise Phase II Restoration Project. The major components of the Lake Surprise Phase II Restoration Project are the removal of excessive accumulated sediments in the lake, the design and implementation of watershed best management practices, the development of an environmental education curriculum, and the implementation of a post-dredging water quality monitoring program.

The eleven remaining critical lakes and ponds, as ranked by the Waterways Team from most to least degraded, are Green Brook Park Lagoon, Upper Echo Lake, Seeley's Pond, Rahway River Park Lake, Warinanco Park Lake and Lagoon, Milton Park Lake, Meisel Pond, **Lower Echo Lake**, Nomahegan Lake, Briant Pond, and Cedar Brook Park Lake. The locations of the above eleven lakes are shown in Figure 1.1.

In an effort to restore these lakes and ponds as natural, recreational, and aesthetic resources, the Union County Division of Parks and Recreation, retained F. X. Browne, Inc. to perform Diagnostic-Feasibility Studies for these remaining eleven critical lakes and ponds. The Phase I Diagnostic-Feasibility Studies have been performed by using a modified monitoring program that generally meets the requirements in 40 CFR, Part 35, Subpart H entitled "Cooperative Agreements for Protecting and Restoring Publicly Owned Freshwater Lakes".

Based on the recommended comprehensive management plans offered as part of the Phase I Diagnostic-Feasibility Studies, Union County will implement the recommended lake and watershed restoration strategies as capital appropriations as operating funds become available. Union County also will use these studies to apply for various sources of state and federal funding.

Individual reports were prepared for each of the eleven Union County study lakes. This document represents the Phase I Diagnostic - Feasibility Report for Lower Echo Lake. Lower Echo Lake is located in Echo Lake Park. This County-owned park is located in the central portion of Union County as shown in Figure 1.1.

Figure 1.1 Location of the Eleven Union County Study Lakes

1.3 Project Objectives

The Diagnostic-Feasibility Studies for all eleven study lakes were conducted in two stages. The diagnostic portion of the studies was conducted to determine current water quality conditions, identify existing problems, and determine the pollutant sources that are responsible for the observed problems. The feasibility aspect of the studies evaluated a variety of lake and watershed restoration alternatives based on the results of the diagnostic study. These alternatives included watershed management practices and in-lake restoration methods. The management plan resulting from the feasibility study includes a description of identified lake and watershed problems, proposed solutions, and a suggested implementation program.

The primary objectives of the Phase I Diagnostic-Feasibility Studies for all eleven County-owned study lakes were:

1. To evaluate the existing water quality conditions in eleven study lakes and to determine the impacts on the recreational uses of these lakes and their surrounding areas,

2. To identify the sources and magnitude of pollutants entering the eleven study lakes,

3. To evaluate feasible control alternatives and restoration methods, and

4. To develop and recommend conceptual lake and watershed management plans that are cost-effective, environmentally sound, acceptable to the public, and can be used as the basis for Phase II Implementation Grant Applications for submission to the U.S. Environmental Protection Agency (U.S. EPA) and other government agencies.

2.0 Lake and Watershed Characteristics

2.1 Lake Morphology

Lower Echo Lake is a 5.3-acre impoundment located in the northeastern portion of Echo Lake Park, in Mountainside and Westfield, New Jersey. Lower Echo Lake is fed by spillover from the dam at Upper Echo Lake, surface runoff, and springs. The watershed of Lower Echo Lake is 2,463 acres including the area of the lake. The watershed boundary is shown in Figure 2.1 and includes the Echo Lake Park area, medium density residential areas, the Echo Lake Park Golf Course, commercial areas located along Route 22, and forested areas located in the Watchung Reservation.

A complete listing of morphometric and hydrologic characteristics of Lower Echo Lake are summarized in Table 2.1.

Table 2.1
Morphometric and Hydrologic Characteristics of Lower Echo Lake

Lake Surface Area	5.3 acres
Lake Volume	7.3 Million Gallons
Average Depth	4.28 feet
Maximum Depth	9.5 feet
Hydraulic Retention Time	4.7 days
Average Discharge	2.64 cfs
Drainage Basin Area (excluding lake area)	2,463 acres

Figure 2.1 Watershed Area Map of Lower Echo Lake

2.2 Benefits and Recreational Uses of Lower Echo Lake

2.2.1 Present Uses

Lower Echo Lake is located in Echo Lake Park, Union County, New Jersey in the municipalities of Westfield and Mountainside. The lake is a recreational focal point for the park. The park is owned and maintained by Union County and is open to the public. The lake is presently used by the public for fishing and boating.

In addition to Echo Lake Park, there are other parks in the area offering a variety of recreational activities to the general public. The park is a very enjoyable place to recreate and has a variety of offerings. There are several other large county parks and attractions (Echo Lake Country Club, Watchung Reservation, Lenape Park, Nomahegan Park, Rahway River Parkway, Galloping Hill Golf Course) making it part of a very significant “green space corridor”. Considering the population density of the area, Lower Echo Lake is an important recreational, economic, and ecologic resource.

2.2.2 Impairment of Recreational Uses

Lower Echo Lake is currently used for fishing and boating; however, these uses are becoming threatened due to siltation, algae growth, and increasing waterfowl and aquatic plant populations. If steps are not taken to improve the water quality in Lower Echo Lake soon, boating will not be possible due to shallow water and dense weed populations.

2.3 Lake Bathymetry

A bathymetric survey of Lower Echo Lake was conducted in September 1996. Water and sediment depth measurements were collected along 12 transects. From these measurements, water depth and sediment thickness maps were prepared and are shown as Figures 2.2 and 2.3, respectively. The water depth map was used to determine the lake's volume, average depth, maximum depth and hydraulic retention time as presented in Table 2.1. Based on the sediment thickness mapping, Lower Echo Lake contains approximately 19,700 cubic yards of unconsolidated sediments. The average sediment thickness is 2.95 feet, and the maximum sediment thickness is 5.50 feet.

Lower Echo Lake was created prior to 1921. The design depth of the lake ranged from three to 20 feet deep, and the design acreage was 8.4 acres. This acreage most likely included the middle lake since the existing acreage of Lower Echo Lake is 5.3 acres. Lower Echo Lake has never been dredged. The design cleaning frequency of the lake was estimated at 30 to 50 years. Lower Echo Lake, which has a lower than expected amount of sediments since Upper Echo Lake serves as a settling basin for the lower lake.

Figure 2.2 Bathymetric Map of Lower Echo Lake

Figure 2.3 Sediment Thickness Map of Lower Echo Lake

2.4 Watershed Characteristics

The Lower Echo Lake watershed covers 2,463 acres, including the 5.3 acre lake. The ratio of the watershed area to the lake surface area is 463:1. This ratio is relatively high, but a combination of watershed management activities such as erosion control and stormwater management and in-lake restoration techniques should effectively reduce the sediments and nutrients entering Lower Echo Lake and improve water quality. Approximately 5 percent of the Lower Echo Lake watershed area lies within Echo Lake Park.

Union County, and therefore the Lower Echo Lake watershed, lies entirely in the Piedmont Plains sub-province of Northern New Jersey. Comprising about one-fifth of the total area of New Jersey, the Piedmont Plains sub-province extends southwestward from the Hudson River, between the Coastal Province and Highlands sub-province, with an extension continuing further south (into Alabama and Georgia), between the Blue Ridge Mountains and the older Appalachians.

Topographically, the Piedmont Plains sub-province includes ridges, hills, and higher elevations rising as much as 400 feet above adjoining lands. This sub-province is primarily a lowland of smooth, rounded hills separated by wide valleys sloping gently down to the Coastal Plain with no clear topographic distinction between these two divisions.

2.4.1 Topography

The Lower Echo Lake watershed area is shown in Figure 2.1. The lake itself is located just east of the Watchung Mountains, which are generally oriented in a northeast to southwest direction. Lands in Union County east of the mountains are gently sloping plains that eventually become areas of tidal marsh land bordering the Arthur Kill and Newark Bay. Lower Echo Lake is located on sloping plains. Portions of the park and watershed have slopes ranging from 2 percent to greater than 15 percent.

2.4.2 Geology

Glacial activity has influenced the majority of the subsurface geology in Northern New Jersey. Though influenced by glaciers, no significant glacial surface deposits, such as stratified drift, ground moraine, or terminal moraine, are found within the Lower Echo Lake watershed area.

Most of the Lower Echo Lake watershed area consists of shale and sandstone of the Brunswick Formation, and much of the area is a glacial "outwash plain" covered to varying depths with sand, silt, gravel, and cobbles in well-defined layers or beds deposited by water from melting glaciers.

2.4.3 Soils

The majority of the soils in Union County belong to the major Gray-Brown Podzolic soil grouping indigenous to the northeastern United States. These soils developed beneath the hardwood forest are common along the eastern coast. Soils derived from soft red shale and sandstone (Brunswick Formation) make up most of Union County. The major soil series of the watershed area is the Boonton soils series. The soils within the watershed are moderately erosive.

2.4.4 Land Use

Land uses in the Lower Echo Lake watershed area are presented in Table 2.2. Land use data were determined from topographic maps by planimetry. Field investigations were used to verify existing land uses delineated from topographic maps.

Table 2.2
Land Use in the Lower Echo Lake Watershed Area

Land Use Category	Area (acres)	Percent (%)
Forest	445	18.1
Open Space	170	6.9
Residential	1,627	66.0
Commercial	200	8.1
Water	21	0.9
Total	**2,463**	**100**

2.5 Population and Socio-Economic Structure

Lower Echo Lake, along with lands within the park, provides a variety of recreational opportunities for the residents of Union County and other nearby counties. The park is located within the New York City Metropolitan Region, and is part of a significant green space corridor for a very densely populated region.

Union County is one of twenty-one counties in the State of New Jersey. Union County comprises an area of 103.4 square miles which makes it the smallest county in the state. The county consists of 21 municipalities, 5 cities, 8 townships, 7 boroughs and 1 town.

Population data for Union County are presented in Table 2.3. The population of Union County was 504,094 in 1980, 493,819 residents in 1990, and 522,541 in 2000. The population reduction from 1980 to 1990 is attributed to the lack of available vacant land for development and a decline in birth rate. The greatest growth rate in Union County occurred in the decades following World War I and II. The population increased by 5.8% from 1990 to 2000.

Table 2.3
Population Data for Union County, New Jersey

County	Population		
	1980	1990	2000
Union County	504,094	493,819	522,541

Source: Union County Data Book, 1991, U.S. Census, 2000.

The population density of Union County was 5,073 persons per square mile in 2000, making it the third most densely populated county in the state (New Jersey Department of Labor). The distribution of people by race in 2000 in Union County was 65.5 percent white, 20.8 percent black, and 10.4 percent other minorities. People of Hispanic origin comprised 19.7 percent of the county's population in 2000.

Union County ranks as one of the more affluent counties in the State of New Jersey. According to the 1980 census, the median family income was $25,266 compared to $22,907 for the state. In 2000, the median family income in Union County was $50,254. Based on 2000 census data, only 9.3 percent of the county reported incomes below the poverty level.

3.0 Monitoring Program

3.1 Primer on Lake Ecology

[*Refer to Appendix A for a comprehensive list of Lake and Watershed Management Terms*]

Ecological Cycle

In a lake, a basic ecological cycle exists. Aquatic plants like algae (microscopic aquatic plants) and macrophytes (large aquatic plants) require nutrients such as phosphorus and nitrogen along with sunlight to grow. Small aquatic animals such as invertebrates (rotifers, protozoa, etc.), snails and insects eat the algae and reproduce. Small forage fish eat the small animals, and, in turn are eaten by larger game fish and other animals. This relationship is called the ecological, or energy pyramid. In a healthy lake, this ecological system exists in proper balance.

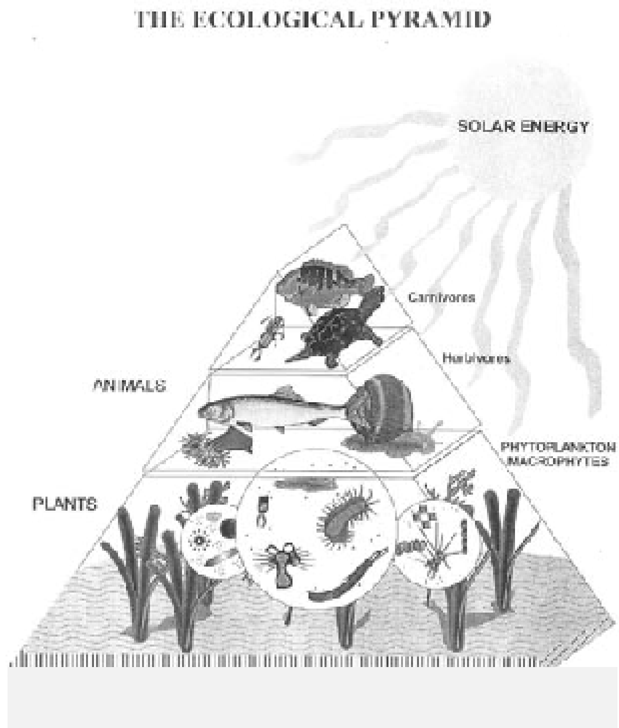


Figure 2 – The Ecological Pyramid of a Typical Lake

When too many nutrients enter a lake, the algae and/or large aquatic plants grow to a point of excess. With a larger population of algae one would expect a nice, large population of fish. However, in reality the excessive plant life is not transferred up the food chain. The small aquatic animals do not eat much of the excess algae (they do not like some of the algae, especially the blue-green algae). Therefore, algae and other plants build up in the lake and destroy the ecological balance of the lake ecosystem. This can result in a reduction in the fish population. It often results in a change in the type of fish found in the lake.

In order to understand the processes that occur in a lake, we must first understand the concept of lake succession or aging.

Lake Succession Over Time

All lakes go through an aging process called ecological succession. Succession is a natural process whereby a lake starts out as an "ecologically" young lake with little vegetation, few nutrients, clear water, and very little unconsolidated (loose) sediment on the bottom. It should be noted that ecological age is different than chronological age. The chronological age is simply the number of years a lake has existed. The ecological age, on the other hand, is a measure of the physical, chemical, and biological conditions of a lake. A lake may be chronologically young (i.e. built only 3 years ago), but it could be ecologically old.

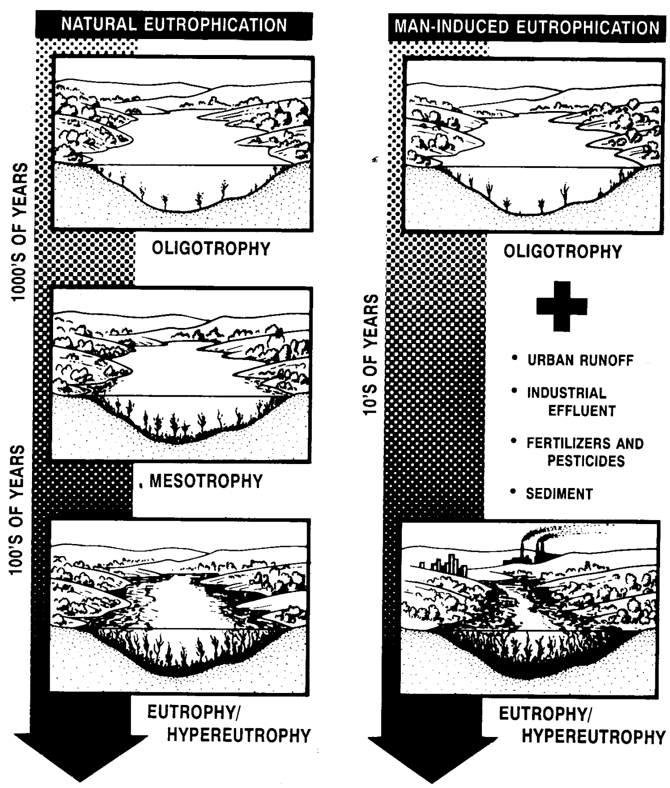
As a lake ages, more nutrients and sediments enter the lake from the surrounding watershed. Usually, the additional nutrients, such as phosphorus and nitrogen, cause an increase in the amount of algae and aquatic weeds. The additional sediment entering the lake settles to the bottom of the lake, increasing the amount of sediment on the lake's bottom.

Thus as a lake ages, it slowly starts to fill up with sediments, algae and aquatic weeds. Initially, the aquatic vegetation is submergent vegetation, beneath the water surface. As the lake fills up further with sediment, emergent vegetation appears above the water surface.

Ultimately, the lake fills in completely with incoming sediment from the watershed and from dying algae, aquatic plants, and animals. The lake transforms into a pond or swamp and eventually, over hundreds or thousands of years, into a forest.

Lake Aging

Lake succession or aging is a natural process that occurs in all lakes. However, the influence of human activities in the watershed can significantly accelerate the aging process.



The lake aging process is accelerated by:

Wastewater Treatment Plant Discharges
Malfunctioning Septic Systems
Agricultural Activities (cropland and pastureland)
Construction Activities
Developed Land
Roadways
Streambank Erosion
Landfills

Human activities in a watershed can add sediments and nutrients such as phosphorus and nitrogen to a lake, resulting in accelerated aging or "cultural eutrophication".

Lake Classification

Lakes are classified by the amount of nutrients (or food) contained in the lake. The Greek word for food is "trophic". Therefore, we classify lakes by their "trophic" or food/nutrient state. Such as:

Oligo = little (little nutrients)
Meso = medium (medium nutrients)
Eu = too much (too much nutrients)

The trophic state refers to the "ecological" age of the lake, not its chronological age. Therefore, an oligotrophic lake is a lake that is ecologically young. Lakes are classified by nutrient level and the presence of aquatic plants as described below.

Oligotrophic lake
ecologically young lake
low level of nutrients
low population of algae and aquatic plants

Mesotrophic lake
ecologically middle-aged lake
moderate level of nutrients
moderate population of algae and aquatic plants

Eutrophic lake
ecologically old lake
high leverl of nutrients
high population of algae and aquatic plants

Lake Problems

Excessive nutrients entering a lake from its watershed cause algae blooms, excessive aquatic plants (macrophytes), lake siltation (settling of sediments in lake, loss of lake volume and capacity), and fishery problems (low dissolved oxygen levels change the fish from game fish to trash fish such as carp). This results in loss of recreation and other lake uses, and can reduce property values around the lake.

Lake problems are caused by point sources and nonpoint sources of pollution. Point sources are wastewater treatment plant discharges. Nonpoint sources cannot be traced to a specific origin, but seems to flow from many different sources.

Nonpoint Source Pollution

Nonpoint source pollution involves three natural processes: stormwater runoff, erosion and sedimentation. Rainwater flowing across land and entering rivers and lakes is known as stormwater runoff. The force of runoff breaking up the soils and detaching individual soil particles is termed erosion. The soil particles are eventually deposited into nearby streams and rivers. This process is called sedimentation. Although a natural part of the water cycle, runoff, erosion and sedimentation have been artificially accelerated by the way humans have chosen to develop land, leading to pollution.

Almost all nonpoint source pollution is caused by stormwater runoff and erosion. Leaky septic systems are also considered nonpoint sources. Rainwater and melting snow run over residential lawns, construction projects, streets and farm fields, picking up pollutants such as soil particles, chemicals and nutrients and carrying them into nearby water bodies. Nonpoint source pollution also occurs from infiltration of pollutants into the ground. Pollutants originating from landfills, abandoned mines, underground storage tanks and septic tanks are possible groundwater pollution sources.

Lake and Watershed Management

A watershed is that area of land that drains directly into a lake, either through rivers, streams, surface runoff, or groundwater. A watershed is best envisioned as a funnel with a glass at the bottom representing a lake. Anything that falls into the funnel will find its way into the glass. Much the same occurs in a watershed, therefore watershed characteristics such as size, land use, slope, and soils play an important role in determining both the quality and quantity of the water that drains to a lake. For this reason, getting to know a lake's watershed and the activities that go on in the watershed are of primary concern to the individuals that manage and enjoy the lake.

Lake management refers to the practice of maintaining lake quality such that attainable lake uses can be achieved (Jones et. al, 2001). Management of a lake is integrally related to management of the surrounding watershed. Watershed management is the process of protecting the lakes, streams, and wetlands in the watershed from point and nonpoint source pollution. It is accomplished by developing an understanding of key factors that affect the water quality of lakes, streams and wetlands and by following a plan of action to prevent, reduce, or minimize those activities within a watershed that may negatively impact water quality. Watershed management consists of many diverse activities including controlling point and nonpoint source pollution, monitoring water quality, adopting ordinances and policies, educating stakeholders, and controlling growth and development in a watershed.

Lake Protection and Restoration

Depending on the physical traits of the lake and watershed, and the quality of the incoming water, certain lakes are suited for particular uses. It can sometimes be difficult to manage a lake for conflicting uses; for example, trout fishing and motorboat racing. A lake cannot be all things to all people, and it can be difficult and expensive to force a lake to support a specific use when it is unrealistic to do so. It is important, therefore, when undergoing a lake protection or restoration project, to set specific goals that are based on a thorough investigation of the lake and its watershed. Lake protection is defined as "The act of preventing degradation or deterioration of attainable lake uses." Lake protection projects are usually undertaken by municipalities or lake associations who fear their lake will suffer from the adverse effects of encroaching development. Lake restoration refers to the act of bringing a lake back to its attainable uses (Jones, et. al., 2001). It is important to be realistic in one's expectations for lake restoration. Nonpoint sources of pollution in a watershed can be difficult to detect and control, and without proper watershed management, lake restoration efforts can fail. A comprehensive watershed management plan should be designed and implemented involving as many watershed stakeholders as possible for best success in lake restoration projects. In any lake project, educating watershed citizens about how their activities affect the lake can be extremely helpful.

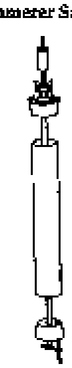
3.2 Study Design and Data Acquisition

Lake water quality samples were collected monthly from May through August 1996 in order to assess the ecological health of the study lakes. The growing season is typically the critical period for most lake systems. During the summer months, lake usage by the public sharply increases and lake problems (if any) are most prevalent (algae blooms, floating mats of algae, dense plant growth, noxious odors, and fish kills).

In addition to the lake samples, sediment samples were collected from the study lakes for physical and chemical analysis. Bathymetric and macrophytic surveys of all eleven study lakes were performed as discussed in Section 2.3 and 3.10 of this report.

The results of the water quality monitoring program for Lower Echo Lake are summarized below. For more detailed information about these monitoring programs, refer to the "Union County Eleven Lakes Quality Assurance/Quality Control Work Plan" that was prepared by F. X. Browne, Inc. (1996).

Kemmerer Sampler



Lake Water Quality Monitoring

One lake water quality monitoring station was established at the deepest portion of the lake. On each study date, lake water samples were collected using a vertical Kemmerer sampler (Model 1290, Wildlife Supply Company) at depths of 0.5 meters below the lake's surface and 0.5 meters above the lake's bottom. The top and bottom discrete lake water samples were subsequently composited together and analyzed for nutrients (total phosphorus, dissolved reactive phosphorus, total Kjeldahl nitrogen, nitrate plus nitrite nitrogen, and ammonia nitrogen), and total suspended solids. The pH of the composited sample was measured in the field using a portable pH meter (Model pHep3, Hanna Instruments).

On each study date, temperature and dissolved oxygen profiles were measured every 0.5 meters using a dissolved oxygen and temperature meter. The Secchi disk transparency was also measured using an 8-inch diameter black and white Secchi disk.

Additional lake samples were collected monthly for chlorophyll a analysis and for phytoplankton and zooplankton identification and enumeration (to genus). A minimum of two discrete lake water samples were collected from the photic zone using a vertical Kemmerer water sampler. The photic zone was defined in this study as a water depth equal to two times the Secchi disk depth. Photic zone discrete samples were then composited together and analyzed for chlorophyll a and used for phytoplankton identification and enumeration. Zooplankton samples were collected by vertically towing a plankton net (80Fm mesh size with a 8-inch orifice) at least five times through the water column. Both phytoplankton and zooplankton identification and enumeration were performed in the laboratory using a Sedgewick-Rafter counting chamber and a microscope equipped with a Whipple Grid. All phytoplanton and zooplankton cell densities (number per volume) were expressed as biomass based on mean cell size.

Sediment Sampling

Three discrete sediment core samples were collected from Lower Echo Lake using a Ogeechee lake sediment sampler (Model 2427, Wildlife Supply Company) equipped with 20 inch corer tubes. Discrete sediment samples were collected along the center line of the lake near the middle and at both ends. Discrete sediment samples were subsequently composited together in the field and submitted to the laboratory for analysis.

The composited lake sediment sample was analyzed for particle size distribution, solids, total phosphorus, total nitrogen, polychlorinated biphenyls (PCBs), pesticides, heavy metals, organic compounds, chlorides, pH, and reactivity for sulfur and cyanide (total concentrations only).

Bathymetric and Macrophyte Surveys

A bathymetric survey and macrophyte survey of Lower Echo Lake were conducted in September 1996. The bathymetric survey involved taking measurements of water depth and sediment depth along pre-determined transects in the lake. The macrophyte survey involved collecting, identifying, and delineating aquatic plants in order to show their distribution within the lake.

Based on the surveys, a bathymetric map (Figure 2.2), an unconsolidated sediment depth map (Figure 2.3), and a macrophyte map (Figure 3.1) were prepared.

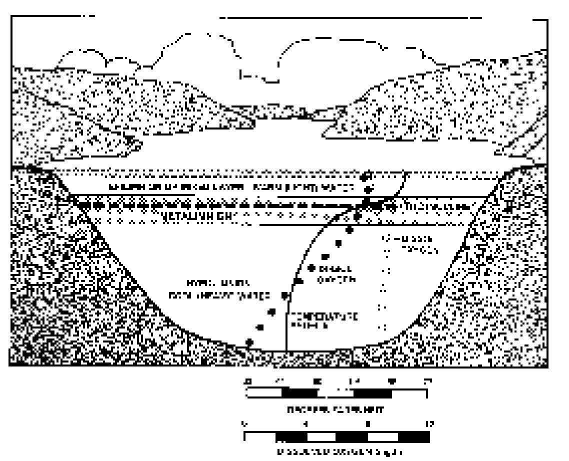
3.3 Lake Water Quality

The results of these analyses are discussed in detail in the following sections of this report. Milton Lake water quality data are presented in Appendix B.

3.3.1 Temperature and Dissolved Oxygen

In late spring or the beginning of summer, deep temperate lakes develop stratified layers of water, with warmer water near the lake's surface (epilimnion) and colder water near the lake's bottom (hypolimnion). As the temperature difference becomes greater between these two water layers, the resistance to mixing increases. Under these circumstances, the epilimnion (top water) is usually oxygen-rich due to photosynthesis and direct inputs from the atmosphere, while the hypolimnion (bottom water) may become depleted of oxygen due to oxygen being consumed by organisms decomposing organic matter at the lake bottom.

Conversely, shallow temperate lakes may never develop stratified layers of water. For these shallow lake systems, wave action caused by the wind may be sufficient to keep the entire lake completely mixed for most of the year. In shallow lakes, low dissolved oxygen levels may occur above the lake sediments even though most of the water in the lake is completely mixed.



Therefore, both shallow and deep temperate lakes can have low dissolved oxygen concentrations near the surface of the lake sediments. If low dissolved oxygen levels occur near the lake bottom, sediments may release significant amounts of nutrients (primarily orthophosphorus and ammonium) back into the lake, thereby allowing for more nutrients for algae and aquatic plant growth.

The dissolved oxygen and temperature profiles in Lower Echo Lake in August 1996 are listed in Table 3.1. During the study period, Lower Echo Lake was thermally stratified. The maximum depth at the monitoring station was 3.0 meters (m) or 9.8 feet. The water temperature ranged from 18 degrees Celsius (°C), or 64.4 degrees Fahrenheit (°F) at a depth of 3 meters to 27°C (80.6 °F) near the surface of the lake. Dissolved oxygen concentrations ranged from 0.2

milligrams per liter (mg/L) at a depth of 3 meters and 5.2 mg/L near the surface of the lake. Dissolved oxygen and temperature profiles for the May, June and July sampling events were similar to profiles measured in August. During all sampling events, the dissolved oxygen concentrations were near zero in the bottom waters.

Table 3.1
Dissolved Oxygen and Temperature Profile Data
Lower Echo Lake - August 1996

Depth (meters)	Temperature (ºC)	(ºF)	Dissolved Oxygen (mg/L)
0.0	27.0	80.6	5.2
0.5	26.0	78.8	3.5
1.0	25.0	77.0	2.0
1.5	23.5	74.3	0.5
2.0	22.0	71.6	0.3
2.5	20.0	68.0	0.3
3.0	18.0	64.4	0.2

In general, the optimal water temperature for trout is 55 to 60 EF (12.8 to 15.6 EC). Trout may withstand water temperatures above 80 EF (26.7 EC) for several hours, but if water temperatures exceed 75 EF (23.9 EC) for extended periods, trout mortality is expected (Pennsylvania State University). A safe minimum dissolved oxygen concentration for trout is 5 mg/L. Warmwater species (i.e. golden shiners, bass, bluegill) which are more typical of New Jersey lakes grow well when water temperatures exceed 80 EF (26.7 EC). For many warm water fish species, 3 mg/L is considered a safe minimum dissolved oxygen concentration. Lower Echo Lake is too warm and the dissolved oxygen levels are too low for coldwater fish such as trout; however, the lake may be able to support warmwater fish species.

3.3.2 pH

In lake ecosystems, changes in pH occur when phytoplankton use carbon dioxide during photosynthesis. Dissolved carbon dioxide reacts with water to form carbonic acid (H_2CO_3). When phytoplankton take up the carbon dioxide dissolved in the lake water during photosynthesis, the result is a decrease in the carbonic acid concentration and a consequent increase in pH. For this reason, the pH of surface waters is higher during an algal bloom than the pH of deeper waters where phytoplankton (suspended microscopic plants) numbers are much lower.

Acidic water contains a relatively high concentration of hydrogen ions, and the higher the concentration of hydrogen ions, the lower the pH. Several anionic salts such as bicarbonates, carbonates, phosphates, silicates, and borates, can bind with hydrogen ions, thereby reducing the acidity of water. When these salts bind with the hydrogen ions, the pH increases and the water is said to be "buffered".

The pH value in Lower Echo Lake ranged from 7.6 to 9.1 standard units (su) with a mean pH value of 7.7 standard units. The water in Lower Echo Lake is considered slightly basic (0.6 to 2.1 standard units above neutral conditions). Under most circumstances, pH values for lakes in the United States range between 6.0 and 9.0 standard units. The higher pH values in the lake are indicative of excessive algae growth.

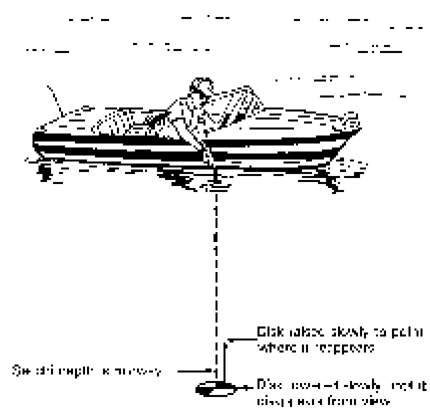
3.3.3 Total Suspended Solids

The concentration of total suspended solids in a lake is a measure of the amount of particulate matter in the water column. Suspended solids are comprised of both organic and inorganic matter.

The total suspended solids concentration in Lower Echo Lake ranged from 4.4 to 19.1 mg/L with a mean concentration of 10.5 mg/L. Total suspended solids concentrations above 10 mg/L, like those in Lower Echo Lake, are considered high for most lake and reservoir systems.

3.3.4 Transparency

The transparency, or clarity, of water is most often reported in lakes as the Secchi disk depth. This measurement is taken by lowering a circular white or black-and-white disk, 20 cm (8 inches) in diameter, into the water until it is no longer visible. Observed Secchi disk depths range from a few centimeters in very turbid lakes to over 40 meters in the clearest known lakes (Wetzel, 1975). Although somewhat simplistic and subjective, this testing method probably best represents the conditions which are most readily visible to the common lake user.



Secchi disk transparency is related to the transmission of light in water and depends on both the absorption and scattering of light. The absorption of light in dark-colored waters reduces light transmission. Light scattering is usually a more important factor than absorption in determining Secchi depths. Scattering can be caused by color, by particulate organic matter, including algal cells, and by inorganic materials such as suspended clay particles in water.

In Lower Echo Lake, the Secchi disk transparency ranged from 0.5 to 1.25 meters (1.6 to 4.1 feet) with a mean transparency of 0.94 meters (3.1 feet). Based on criteria established by the United States Environmental Protection Agency (U.S. EPA 1980), Secchi disk transparencies that are less than 1.5 meters indicate eutrophic (highly productive) conditions. Therefore, Lower Echo Lake is highly eutrophic (hyper-eutrophic) based on the EPA criterion for Secchi Disk transparency.

3.3.5 Phosphorus Concentrations

Phosphorus is a major nutrient required for the growth of algae and macrophytes in lakes. Dissolved reactive phosphorus is the form of phosphorus this is most readily available to support aquatic growth. In most lake systems, phosphorus is the limiting nutrient and therefore is the nutrient which controls the amount of aquatic plant growth (vascular plants and algae).

Total phosphorus represents the sum of all forms of phosphorus, and includes dissolved and particulate organic phosphates from algae and other organisms, inorganic particulate phosphorus from soil particles and other solids, polyphosphates from detergents, and dissolved orthophosphates. Soluble orthophosphate is the phosphorus form that is most readily available for algal uptake and is usually reported as dissolved reactive phosphorus. Total phosphorus levels are strongly affected by the daily phosphorus loads that enter the lake. Soluble orthophosphate levels, however, are affected by algal consumption during the growing season.

During the study period, the total phosphorus concentrations in Lower Echo Lake ranged from 0.115 to 0.702 mg/L as phosphorus (P) with a mean concentration of 0.390 mg/L as P, as shown in Table 3.2. The dissolved reactive phosphorus concentrations ranged from 0.022 to 0.471 mg/L as P, with a mean concentration of 0.218 mg/L as P.

Table 3.2
Mean and Range of Phosphorus Concentrations in Lower Echo Lake

Total Phosphorus (mg/L as P)	Dissolved Reactive Phosphorus (mg/L as P)
0.390 [0.115- 0.702]	0.218 [0.022-.471]

Note: Range of concentrations present inside of brackets [ ].

Dissolved reactive phosphorus is the phosphorus form that is readily available for algae and macrophytes to use. In many lake systems during the summer months, dissolved reactive phosphorus concentrations are very low (less than 0.001 mg/L) since it is readily used by plants and algae as soon as it becomes available. The mean total phosphorus concentration in the lake of 0.390 mg/L is typical of eutrophic lake conditions. Based on criteria set forth by the U.S. EPA, a lake system is classified as eutrophic when total phosphorus concentrations exceed 0.03 mg/L as P. The mean total phosphorus concentration in Lower Echo Lake of 0.39 mg/L is indicative of hyper-eutrophic conditions.

3.3.6 Nitrogen

Nitrogen compounds are also important for algae and aquatic macrophyte growth. The common inorganic forms of nitrogen in water are nitrate (NO_3^-), nitrite (NO_2^-), and ammonia (NH_3). The form of inorganic nitrogen present depends largely on dissolved oxygen concentrations. Nitrate is the form usually found in surface waters, while ammonia is only stable under anaerobic (low oxygen) conditions. Nitrite is an intermediate form of nitrogen which is unstable in surface waters. Nitrate and nitrite (total oxidized nitrogen) are often analyzed together and reported as NO_3+NO_2-N, although nitrite concentrations are usually insignificant. Total Kjeldahl nitrogen (TKN) concentrations include ammonia and organic nitrogen (both soluble and particulate forms). Organic nitrogen is determined by subtracting ammonia nitrogen from total Kjeldahl nitrogen. Total nitrogen is calculated by summing the nitrate-nitrite, ammonia, and organic nitrogen fractions together.

The mean total nitrogen, organic nitrogen, nitrate plus nitrite nitrogen, and ammonia nitrogen concentrations, along with ranges of concentrations in Lower Echo Lake, are presented in Table 3.3.

Table 3.3
Mean and Range of Nitrogen Concentrations in Lower Echo Lake

Total Nitrogen (mg/L as N)	Organic Nitrogen (mg/L as N)	Nitrate/Nitrite (mg/L as N)	Ammonia (mg/L as N)
2.15 [0.95- 4.22]	1.39 [0.37- 2.79]	0.32 [0.02- 0.73]	0.44 [0.10- 0.84]

Note: Range of concentrations present inside of brackets [ ].

The mean total nitrogen concentration in Lower Echo Lake is 2.15 mg/L. Most of the nitrogen measured in Lower Echo Lake occurs in the organic form. Nitrate plus nitrite and ammonia concentrations were relatively low, indicating high uptake rates by algae.

3.3.7 Limiting Nutrient

Algal growth depends on a variety of nutrients including macronutrients such as phosphorus, nitrogen, and carbon, and trace nutrients such as iron, manganese, and other minerals. According to Liebig's Law of the Minimum, biological growth is limited by the substance that is present in the minimum quantity with respect to the needs of the organism. Nitrogen and phosphorus are usually the nutrients limiting algal growth in most natural waters.

Depending on the species, algae require approximately 15 to 26 atoms of nitrogen for every atom of phosphorus. This ratio converts to 7 to 12 mg of nitrogen per 1 mg of phosphorus on a mass basis. A ratio of total nitrogen to total phosphorus of 15:1 is generally regarded as the dividing point between nitrogen and phosphorus limitation (U.S. EPA, 1980). Identification of the limiting nutrient becomes more certain as the total nitrogen to total phosphorus ratio moves farther away from the dividing point, with ratios of 10:1 or less providing a strong indication of nitrogen limitation and ratios of 20:1 or more strongly indicating phosphorus limitation.

Inorganic nutrient concentrations may provide a better indication of the limiting nutrient because the inorganic nutrients are the forms directly available for algal growth. Ratios of total inorganic nitrogen (TIN = ammonia, nitrate, and nitrite) to dissolved reactive phosphorus (DRP) greater than 12 are indicative of phosphorus limitation, ratios of TIN:DRP less than 8 are indicative of nitrogen limitation, and TIN:DRP ratios between 8 and 12 indicate either nutrient can be limiting (Weiss, 1976).

The total nitrogen to total phosphorus ratio (TN:TP) in Lower Echo Lake was 6:1 and the total inorganic nitrogen to dissolved reactive phosphorus ratio (TIN:DRP) was 8.3:1. Based on these nutrient ratios, either nutrient may be limiting .

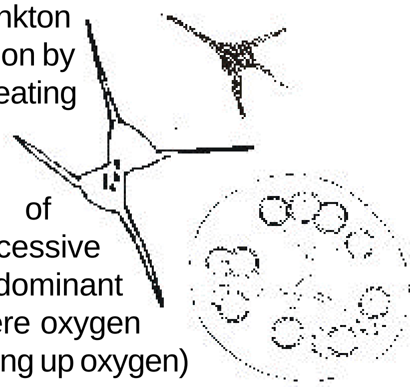
3.3.8 Chlorophyll a

Chlorophyll a is a pigment which gives plants their green color. Its function is to convert sunlight to chemical energy in the process of photosynthesis. Because chlorophyll a constitutes about 1 to 2 percent of the dry weight of planktonic algae, the amount of chlorophyll a in a water sample is an indicator of phytoplankton biomass.

The chlorophyll a concentration in Lower Echo Lake ranged from 17.8 to 207.3 micrograms per liter (Fg/L) with a mean concentration of 88.7 Fg/L. Based on USEPA criteria, a lake is classified as eutrophic when chlorophyll a concentrations exceed 6.0 to 10.0 Fg/L. Therefore, Lower Echo Lake is highly eutrophic based on chlorophyll a concentrations. Algicides were applied to Lower Echo Lake during the study period, which typically reduces the number of phytoplankton and the chlorophyll a concentration. If algicides were not applied to this lake, the chlorophyll a concentration would likely have been even higher.

3.3.9 Phytoplankton

Phytoplankton are microscopic algae that have little or no resistance to currents and live free floating and suspended in open water. Their forms may be unicellular, colonial, or filamentous. As photosynthetic organisms (primary producers), phytoplankton form the foundation of the aquatic food web and are grazed upon by zooplankton (microscopic animals) and herbivorous fish (plant-eating fish).



A healthy lake should support a diverse assemblage of phytoplankton represented by a variety of algal species. Excessive phytoplanktonic growth, which typically consists of a few dominant species, is undesirable. Excessive growth can result in severe oxygen depletion in the water at night, when the algae are respiring (using up oxygen) and not photosynthesizing (producing oxygen). Oxygen depletion can also occur after an algal bloom when bacteria grow and multiply using dead algal cells as a food source. Excessive growths of some species of algae, particularly members of the blue-green group, may cause taste and odor problems, release toxic substances to the water, or give the water an unattractive green soupy or scummy appearance.

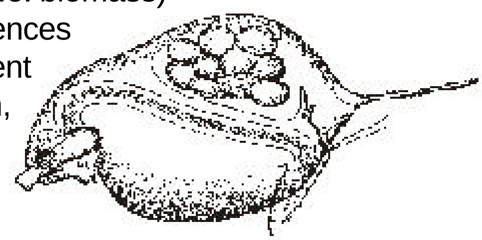
Planktonic productivity is commonly expressed by enumeration and biomass. Enumeration of phytoplankton is expressed as cells per milliliter (cells/mL). Biomass is expressed on a mass per volume basis as micrograms per liter (mg/L). Of the two, biomass provides a better estimate of the actual standing crop of phytoplankton in lakes.

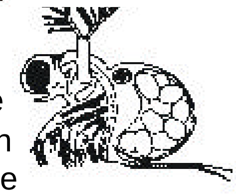
During the study period, seven taxa (groups) of phytoplankton were identified in Lower Echo Lake including Bacillariophyta (diatoms), Chlorophyta (green algae), Chrysophyta (golden brown algae), Cryptophyta (cryptomonads), Cyanophyta (blue-green algae), Euglenphyta (euglena), and Pyrrhophyta (dinoflagellates). The phytoplanktonic total biomass ranged from 4,393 to 18,543 micrograms per liter (ug/L) with a mean of 10,216 ug/L, which is relatively high. However, there are no generally accepted standards for phytoplankton biomass. The lowest total biomass levels were observed in the month of July and the highest in May. Phytoplankton data are presented in Appendix C.

Another indication of eutrophication is the dominance of blue-green algae (Cyanophyta) in lakes; however, since algicides were applied to Lower Echo Lake, a lower than average blue-green algae population was observed during the sampling period. If algicides were not applied to this lake, it is likely that blue-green algae would be present in large numbers.

3.3.10 Zooplankton

Zooplankton are microscopic animals whose movements in a lake are primarily dependent upon water currents. Zooplankton remain suspended in open water. Major groups of zooplankton include protozoa, rotifers and crustaceans. Crustaceans are further divided into copepods and cladocerans (i.e. water fleas). Zooplankters are generally smaller than 2 millimeters (one-tenth of an inch) in size and primarily feed on algae, other zooplankton, and plant and animal particles. Zooplankton grazing can have a significant impact on phytoplankton species composition and productivity (i.e. biomass) through selective grazing (e.g. size of zooplankton influences what size phytoplankton are consumed) and nutrient recycling. Zooplankton, in turn, are consumed by fish, waterfowl, aquatic insects, and others, thereby playing a vital role in the transfer of energy from phytoplankton to higher trophic levels.





In Lower Echo Lake, the zooplankton biomass ranged from 91 to 478 Fg/L with a mean of 253 Fg/L. The lowest zooplankton biomass levels were observed in May and the highest biomass levels were observed in June. In general, the zooplankton biomass order of dominance in Lower Echo Lake was copepods followed by rotifers, cladoceras, and protozoans.

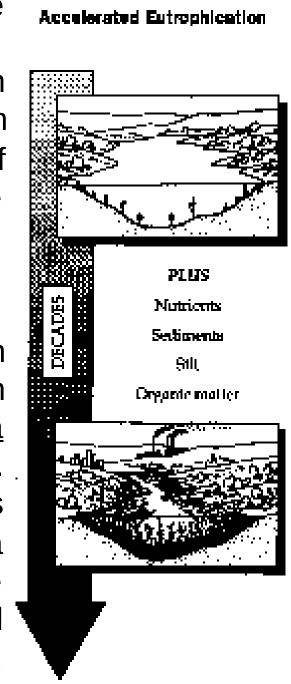
Zooplankton data are often used in conjunction with fishery surveys to assess a lake's fishery. In particular, the mean length of crustacean zooplankters collected during the spring and mid-summer is compared to one another and the results can be used to assess a lake's fishery (Mills and Green, 1987). In Lower Echo Lake, the mean length of crustacean zooplankton ranged from 0.45 millimeters (mm) in June to 0.59 mm in May.

These mean zooplankton lengths in early-spring and summer are quite small and are typical of lakes with low predator to prey ratios. Under such circumstances, a lake's fishery can consist of many undersized planktivorous fish (i.e. blue gill, white perch, yellow perch, pumpkinseed). With too many undersized planktivorous fish and too few piscivorous fish (i.e. bass, pickerel) to control them, overgrazing of large-bodied zooplankters is inevitable. If the zooplankton population is low, the algae population is high because there are not enough zooplankton to eat and control the algae population.

Based on the zooplankton data, Lower Echo Lake most likely contains an unbalanced fishery. An unbalance fishery may be caused by the over harvesting of larger gamefish by anglers or indirectly related to poor lake water quality. Poor lake water quality may severely impair reproductive success rates, growth rates, and survival rates of some gamefish.

3.3.11 Trophic State Index

Eutrophication is a natural process where sediments and nutrients from the watershed accumulate in the lake. The eutrophication process is often accelerated by the activities of people. Contrary to popular opinion, a eutrophic lake is not "dead;" it is actually suffering from an over-abundance of living organisms. The organisms in a eutrophic lake are excessive in number, but usually represent relatively few species. In contrast, an oligotrophic lake is one containing relatively small numbers of organisms representing many species. Mesotrophic lakes have intermediate conditions between eutrophic and oligotrophic lakes.



The Trophic State Index (TSI) developed by Carlson (1977) is among the most commonly used indicators of lake trophic state. The Carlson TSI is actually composed of three separate indices based on measurements of total phosphorus concentrations, chlorophyll a concentrations, and Secchi disk transparencies for a variety of lakes. Total phosphorus is an important parameter because phosphorus is often the limiting nutrient for algal growth in lakes. Chlorophyll a is a plant pigment present in all algae and is used to express indirectly the biomass of algae in a lake. Secchi disk depth, as discussed previously, is a common measure of the transparency of the water in a lake.

Summer average values for total phosphorus, chlorophyll a, and Secchi depth are logarithmically converted to a scale of relative trophic state ranging from 1 to 100. Increasing values for the Trophic State Index are indicative of increasing trophic state in a lake. In general, index values less than 40 are indicative of oligotrophic conditions, while index values greater than 50 are indicative of eutrophic lake conditions.

The mean Carlson Trophic State Index (TSI) values was 90 for total phosphorus, 75 for chlorophyll a, and 61 for Secchi disk transparency. Based on the mean TSI values, Lower Echo Lake is classified as a highly productive or hyper-eutrophic lake.

3.4 Macrophytes

Aquatic vegetation ranges from tiny microscopic algae or phytoplankton to large vascular aquatic plants which are called macrophytes. Macrophytes can be found rooted to the lake bottom or floating on the lake's surface. Based on growth and habitat characteristics, macrophytes generally can be classified in one of three categories: submerged aquatic vegetation, floating aquatic vegetation, and emergent aquatic vegetation. Submerged aquatic plants live and grow completely underwater or just up to the surface of the water. A few submerged species protrude just above the water surface when in flower. Floating aquatic plants are those plants whose leaves float on the surface of the water. These plants may or may not be anchored to the bottom of the lake via stems or roots. Emergent aquatic plants have their upper stems and leaves protruding above the surface of the water. These plants are always attached directly to the lake bottom via root systems.

A macrophyte survey of Lower Echo Lake was conducted in September 1996. Plants were collected, identified to genus, and mapped to show the distribution within the lake. The distribution of macrophytes in Lower Echo Lake is illustrated in Figure 3.1. The aquatic plant community in Lower Echo Lake primarily consisted of Spattordock (*Nuphar Sp.*), Coontail (*Ceratophyllum demersum*), and Slender Pondweed (*Potamogeton Sp.*). A less dominant type of macrophytes included Marsh Purslane (*Portulaca Sp*.) In general, the density of macrophytes in Lower Echo Lake is considered excessive.

Figure 3.1 Macrophyte Map of Lower Echo Lake

3.5 Comparison of Union County Lakes Water Quality

Water quality comparisons of the eleven study lakes were based on a trophic state ranking system as shown in Table 3.4. This ranking system assigned point values to the Carlson's Trophic State Index (TSI) values for total phosphorus, chlorophyll a, and Secchi disk transparency for each study lake. Next, the point values for the three parameters were added together for each lake and these total point values provided the basis for lake water quality data comparisons as described below.

For all three parameters (total phosphorus, chlorophyll a, and Secchi disk transparency), lake TSI values received scores ranging from 1 to 11 points. For example, the lake with the highest TSI value for phosphorus (worst water quality) received 1 point, while the lake with the lowest TSI value for phosphorus (best water quality) received 11 points as shown in Table 3.4. This scoring procedure was also performed for both chlorophyll a and Secchi disk transparency TSI values. Next, for each study lake, the "Individual TSI Ranked Scores" for all three parameters were summed, thereby resulting in a "Total TSI Ranked Score". Based on this scoring procedure, the "Total TSI Ranked Scores" could theoretically range from 3 to 33 points. Using the "Total TSI Scores", the eleven study lakes were subsequently ranked relative to one another (Relative Ranking) from lowest (worst water quality) to highest (best water quality) as shown in Table 3.4.

In Table 3.4, the Total TSI Ranked Scores for the eleven study lakes ranged from 7 to 33 points. Of these County lakes, Warinanco Park Lake recorded the poorest water quality and Seeley's Pond recorded the best water quality. It should be noted that the majority of the study lakes were treated with algicides throughout the study period, therefore the TSI values for Secchi disk transparency and chlorophyll a data and subsequently their Total TSI Ranked Scores are likely "artificially" lower than expected. Of the study lakes, only Briant Park Pond and Seeley's Pond were not chemically treated with algicides during the study period.

Based on the data presented in Table 3.4, Lower Echo Lake was ranked the sixth, meaning that five of the study lakes had poorer water quality than did Lower Echo Lake. As stated above, Lower Echo Lake was treated with algicides during the study period, therefore its ranking may be higher than expected.

Table 3.4
Lake Water Quality Data Comparisons Using Carlson's Trophic State Index Values

Lake Name	TSI Values			Algicides Used	Total TSI Ranked Score	Relative Ranking
	Total P	Secchi Disk	Chlorophyll-a			
Warinanco Park Lake (WPL)	91 [2]	76 [2]	75 [3]	Yes	7	1
Cedar Brook Park Lake (CBPL)	80 [7]	76 [1]	77 [2]	Yes	10	2
Briant Park Pond (BPP)	82 [6]	73 [4]	81 [1]	No	11	3
Green Brook Park Lake (GBPL)	97 [1]	74 [3]	76 [9]	Yes	13	4
Nomahegan Park Lake (NPL)	87 [4]	71 [6]	74 [6]	Yes	16	5
Lower Echo Lake (LEL)	**90 [3]**	**61 [10]**	**75 [4]**	**Yes**	**17**	**6**
Meisel Pond (MP)	83 [5]	73 [5]	71 [8]	Yes	18	7
Rahway River Park Lake (RRPL)	76 [10]	69 [7]	74 [5]	Yes	22	8
Upper Echo Lake (UEL)	77 [9]	66 [8]	73 [7]	Yes	24	9
Milton Lake (ML)	79 [8]	62 [9]	63 [10]	Yes	27	10
Seeley's Pond (SP)	61 [11]	59 [11]	49 [11]	No	33	11

Note: Values in brackets [ ] are the "Individual TSI Ranked Scores" for total phosphorus, Secchi disk transparency, and chlorophyll-a for each lake.

3.6 Lake Water Quality Summary

Based upon the results of the lake monitoring program and the U.S. EPA trophic state criteria, including total phosphorus, chlorophyll a, Secchi disk transparency, and Carlson's TSI, Lower Echo Lake is classified as a thermally stratified hyper-eutrophic lake system. The limiting nutrient in the lake may be either nitrogen or phosphorus. The dissolved oxygen levels within the hypolimnion tend to become depleted during the growing season. The amount of macrophytes in Lower Echo Lake is considered excessive, and the phytoplankton biomass was relatively high despite the fact that algicides were applied to the lake.

3.7 Lake Sediment Analyses

As part of a lake study, lake sediments are often collected and analyzed for nutrients, texture, and accumulated pollutants, such as pesticides, herbicides, and metals. Sediment test results are used to assess the potential impacts of any accumulated pollutants on the aquatic community, investigate the internal release of nutrients by in-lake sediments, and determine how to properly dispose of lake sediments during a lake dredging project.

In September 1996, one composited lake sediment sample was collected and analyzed for particle size distribution, solids (total, volatile and percent composition), nutrients (total phosphorus, total nitrogen), heavy metals, pesticides, polychlorinated biphenyl compounds, herbicides, volatile organic compounds, and semi-volatile compounds. With the exception of particle size and solids data, the above data were analyzed as total (bulk) concentrations and are presented on a dry weight basis.

The physical characteristics of the sediments in Lower Echo Lake are presented in Table 3.5. Based on weight, the sediments in Lower Echo Lake contain 40.6 percent water and 59.4 percent solids. Of these solids, the lake sediments are primarily composed of inorganic materials. Based on particle size, most of the solids are classified as silt as shown in Table 3.5.

Table 3.5 Physical Characteristics of Sediments in Lower Echo Lake	
Parameters	**Results**
Composition:	
Percent Solids	40.6
Particle Size Distribution:	
Percent Gravel	8
Percent Sand	13
Percent Silt	55
Percent Clay	24
Total	100

With regard to sediment disposal and sediment reuse, the sediment analyses should meet the Soil Cleanup Criteria proposed by the New Jersey Department of Environmental Protection (NJDEP). Sediment reuse, such as fill material, is obviously the least expensive manner in which to dispose of dredged lake sediments. Under the Soil Cleanup Criteria, one set of criteria applies to the disposal of sediments at residential type lands, while the second set of criteria applies to the disposal of sediments at non-residential type lands. Of the two sets of criteria, the residential criteria are more stringent.

Both sets of criteria list a variety of pollutants along with their corresponding proposed state regulatory levels. These pollutants are classified as heavy metals, polychlorinated biphenyl compounds (PCBs), pesticides, herbicides, volatile organic compounds (VOCs), and semi-volatile organic compounds (SOVs). The regulatory levels are based on total concentrations and are expressed on a dry weight basis.

The hazardous constituents in the composited sediment sample collected from Lower Echo Lake were compared to the NJDEP proposed Soil Cleanup Criteria for both residential and non-residential land classifications. The total concentrations of the above parameters that exceeded the residential or both the residential and non-residential Soil Cleanup Criteria are presented in Table 3.6. All sediment quality data are presented in Appendix C.

Table 3.6
Total Concentrations of Various Constituents in Lake Sediments Exceeding the Proposed NJDEP Soil Cleanup Criteria

Parameter	Measured Concentration (mg/Kg)	Residential Criteria (mg/Kg)	Non-Residential Criteria (mg/Kg)
Semi-volatile Compounds			
Benzo(a)anthracene	1.2	0.9	4
Benzo(a)pyrene	1.4	0.66	0.66
Indeno(1,2,3-cd)pyrene	1.3	0.9	4

In Lower Echo Lake, Benzo(a)anthracene, Benzo(a)pyrene, and Indeno(1,2,3-cd)pyrene exceeded the proposed NJ DEP Soil Cleanup Criteria as shown in Table 3.6. All three materials exceeded the residential criteria, while Benzo(a)pyrene exceeded both the residential and non-residential criteria. Disposal of these sediments will be more difficult and costly than uncontaminated sediment. The contaminated sediment can either be capped with clean soil or the sediment must be transported to a hazardous waste landfill.

All proposed lake dredging projects are reviewed by the NJDEP on a case-by-case basis. The NJDEP Soil Cleanup Criteria are informal guidelines that have not been promulgated by the State of New Jersey as formal regulatory levels.

4.0 Pollutant Budgets

Pollutants can enter a lake from both point and nonpoint sources. Point sources are defined as all wastewater effluent discharges within a watershed. Point source pollutants may be discharged into streams and then transported to lakes or directly discharged into lakes. All other pollutant sources within a watershed are classified as nonpoint sources. Nonpoint source pollutants are transported to lakes by tributaries, direct runoff (i.e., overland flow), shallow groundwater, the atmosphere (as dry and wet fallout), and in-lake sediments (internal release mechanisms).

In general, the quantities of nonpoint source pollutants to lakes increase dramatically as a result of man. Human activities, such as agriculture, silviculture, on-site wastewater treatment (septic systems), and land development (construction), dramatically increase the quantity of nonpoint source pollutants to streams, rivers, and lakes. Even after construction has ended, developed lands (residential, commercial, and industrial areas) will continue to release much higher quantities of nonpoint source pollutants to watercourses. Though more difficult to quantify, nonpoint sources are extremely important because they often constitute the major source of pollutants to lakes.

The water quality of lakes is dependent on the water quality that enters from the surrounding watershed. Therefore, a thorough understanding of the watershed (soils, slopes, vegetative cover, land uses, nonpoint sources, etc.) is necessary to explain the water quality in a lake. In order to construct pollutant budgets for a lake, the following information is required: the water quality of streams, the hydrologic characteristics of streams, the morphometric characteristics of the lake (surface area, volume, mean depth, etc.), the characteristics of the surrounding watershed, and the quantity and quality of stormwater runoff and groundwater inflow.

4.1 Pollutant Budget

In order to develop a comprehensive lake and watershed management plan, the source and magnitude of incoming nutrients (namely phosphorus and nitrogen) and suspended solids to the lake must be identified and quantified. Nutrient and sediment loadings to a lake can be assessed by two different approaches: the lake and stream monitoring approach or the unit area loading (UAL) approach (U.S. EPA, 1980). The monitoring approach requires the following: (1) the collection of hydrologic (discharge) data for major tributaries to a lake and (2) the collection and analysis of stream water samples for both wet and dry weather periods. Stream hydrological data and water quality data are then used to determine actual pollutant loadings. The unit areal loading approach is based on the premise that different types of land use contribute different quantities of pollutants through runoff. Unit areal loading values have been determined in many parts of the country and are readily available in literature. In this study, an annual pollutant budget was estimated for Lower Echo Lake based on land use and unit areal pollutant loadings.

4.2 Nutrient and Sediments Loading Estimates Using the UAL Approach

The UAL approach was applied to Lower Echo Lake based on the predominate land uses within the surrounding watershed. In order to estimate pollutant budgets, nutrient and sediment export coefficients compiled by Uttormark et al. (1974), Reckhow et al. (1980), and the U.S. EPA (1980) were evaluated and specific coefficients were selected based on their applicability to the Lower Echo Lake watershed.

Based on land use and typical unit area loadings, most of the pollutant loading to Lower Echo Lake is coming from residential land. In fact, approximately 62% of the phosphorus load and 60% of the nitrogen and suspended solids loads are coming from residential land. Residential land uses comprise 66 percent of the watershed. The estimated pollutant loads for the Lower Echo Lake watershed are listed in Table 4.1.

4.3 Phosphorus Reduction Requirements

Based on the water quality data collected during this study, phosphorus was identified as the "limiting" nutrient in Lower Echo Lake most of the time; however, nitrogen was limiting on some sampling dates. Therefore, in general, it is phosphorus that controls the overall degree or level of eutrophication in the lake. If lake phosphorus concentrations were to decrease, the overall water quality in the lake should improve. Based on this study, the average seasonal total phosphorus concentration in Lower Echo Lake is 0.39 mg/L. Phosphorus loadings to the lake should be reduced until the average seasonal total phosphorus concentration is below 0.030 mg/L.

Table 4.1
Estimated Unit Areal Loadings for the Lower Echo Lake Watershed*

Land Use (%Watershed/# Acres	Parameter	Runoff Coefficient (lbs/acre/yr)	Annual Pollutant Load (lbs/yr)	Percent of Total Load
Undisturbed Forested, Undisturbed Mixed Forest (18.1%, 444.73)	Total Phosphorus Total Nitrogen Total Suspended Solids	0.25 0.2 100	111 889 44,473	8 10 8
Open Space (6.9%, 170.56)	Total Phosphorus Total Nitrogen Total Suspended Solids	0.75 6.0 220	128 1,023 37,523	10 12 7
Developed Areas, Residential (66%, 1626.69)	Total Phosphorus Total Nitrogen Total Suspended Solids	0.50 3.25 200	813 5,286 325,338	62 60 60
Developed Areas, Commercial (8.1%, 200.27)	Total Phosphorus Total Nitrogen Total Suspended Solids	1.3 7.5 660	260 1,502 132,178	20 17 24
Water (Direct Precipitation)** (0.9%, 21.09)	Total Phosphorus Total Nitrogen Total Suspended Solids		1.7 130 220	0.13 1.5 0.04
TOTALS- (100%/2463.34)	**Phosphorus Load** **Nitrogen Load** **Total Suspended Solid Load**		**1,315** **8,831** **539,732**	

* These loads only account for stormwater runoff loads; they do not include loads from groundwater or nutrient recycling in the lake.

** Pollutant loads are based on an average rainfall of 46 inches per year and pollutant deposition concentrations of 0.008 mg/L for phosphorus, 0.59 mg/L for total nitrogen, and 1.0 mg/L for total suspended solids.

5.0 Identification of Problem Areas

As part of the Lower Echo Lake study, a watershed evaluation was performed to identify nonpoint source pollution problem areas within the Lower Echo Lake watershed. Several types of nonpoint source pollution problems were observed in the watershed including shoreline erosion and urban stormwater management problems. In addition, based on the results of the bathymetric survey and on observations during the watershed evaluation, excessive sedimentation has occurred in Lower Echo Lake resulting in excessive amounts of sediment in the lake.

5.1 Shoreline Erosion

In general the shoreline of Lower Echo Lake is well stabilized. A 150 foot section of shoreline on the southern side of the lake is severely eroded (due to Hurricane Floyd)and should be stabilized with vegetative and structural measures. Several trees blew over into the lake during the hurricane taking big chunks of soil with them. The scarred area left behind is now highly erodible.

Shoreline Erosion around Lower Echo Lake

5.2 Streambank Erosion

A section of streambank below the Lower Echo Lake Dam is also severely eroded as a result of Hurricane Floyd. This area should be stabilized using bioengineering techniques in conjunction with structural methods.


Streambank erosion below Lower Echo Lake Dam

5.2 Waterfowl

Excessive numbers of waterfowl can create major water quality problems for lakes. The large numbers of waterfowl, mainly Canada geese and gulls, aggravate shoreline erosion problems by walking up and down the lake banks. The waterfowl droppings are also a problem and are a direct source of phosphorus, nitrogen, and bacteria to the lake. The large amount of waterfowl droppings around the lake is a significant problem at Lower Echo Lake.

5.3 Urban Stormwater Management

Based on our field investigations, it is apparent that untreated stormwater runoff from impervious areas, such as parking lots and roads, enters the storm sewers and streams leading to Lower Echo Lake. This untreated stormwater contains high concentrations of sediments and nutrients.

6.0 Recommended Management Plan

In developing a recommended management plan for Lower Echo Lake, both in-lake management alternatives and watershed management alternatives were evaluated. The first priority in all management programs is to determine whether watershed management practices can be implemented to reduce the pollutants entering the lake. Because nonpoint source pollutants account for 100 percent of the nutrient and sediment loadings to Lower Echo Lake, it is critical that the lake and watershed restoration plan focuses on watershed controls in addition to in-lake restoration techniques.

During the development of the watershed management plan, the following criteria were used to evaluate the potential management alternatives:

Effectiveness:	how well a specific management practice meets its goal
Longevity:	reflects the duration of treatment effectiveness
Confidence:	refers to the number and quality of reports and studies supporting the effectiveness rating given to a specific treatment
Applicability:	refers to whether or not the treatment directly affects the cause of the problem and whether it is suitable for the region in which it is considered for application
Potential for Negative Impacts:	an evaluation should be made to ensure that a proposed management practice does not cause a negative impact on the lake ecosystem
Capital Costs:	standard approaches should be used to evaluate the cost-effectiveness of various alternatives
Operation and Maintenance Costs:	these costs should be evaluated to help determine the cost-effectiveness of each management alternative

The recommended management plan for Lower Echo Lake is based upon the following: (1) lake water quality data, (2) watershed tours, (3) estimated pollutant budgets, and (4) the goals as established by the Union County Waterways Team.

Recommended in-lake restoration alternatives for Lower Echo Lake include lake dredging, possible lake aeration, and batch alum treatment. Watershed management practices that are recommended for Lower Echo Lake include shoreline stabilization, streambank stabilization, watershed investigations, waterfowl control, urban stormwater management, and homeowner practices. In addition, a public education program, water quality monitoring program, fish stocking, and institutional approaches are recommended.

The recommendations provided in this lake and watershed management plan will help the municipalities within the watershed to comply with the new EPA Stormwater Phase II Final Rule. MS-4 municipalities were required to submit an application to the NJDEP to be included in the General Phase II Stormwater Permit by March 2003 and are now required to implement the following minimum control measures to reduce nonpoint source pollutants from stormwater runoff:

1. Public education and outreach
2. Public participation and involvement
3. Illicit discharge detection and elimination
4. Construction site runoff control
5. Post-construction runoff control
6. Pollution prevention and good housekeeping

The recommendations in this report cover most of these requirements including a well run public education program, storm sewer stenciling, identification of potential BMP retrofit areas to improve stormwater quality, and a more effective street sweeping program.

6.1 In-Lake Treatment

6.1.1 Lake Dredging

The physical removal of lake sediments can be used to achieve one or more objectives and is often referred to as the “ultimate face-lift”. Overall, the costs for dredging are high, but the benefits are long-term, as long as control measures are implemented to minimize the amount of sediment entering the lake. Lower Echo Lake has never been dredged before.

Lower Echo Lake contains approximately 19,700 cubic yards of unconsolidated sediment that should be removed by dredging. Lower Echo Lake should be mechanically dredged and sediments should be disposed of.

Based on the sediment chemistry data, sediments in Lower Echo Lake are contaminated. Potential disposal areas for contaminated sediments include hazardous waste landfills and available non-residential land. County owned parkland may be acceptable for sediment disposal, but site remediation techniques such as capping the sediments may be required. The DEP has indicated that they will consider disposal sites for contaminated sediments on a case by case basis. Currently, DEP has no specific guidelines for the disposal of contaminated sediments. Finding an acceptable disposal site for the sediments may be difficult, but according to DEP personnel, it is not impossible.

A dredging feasibility study should be performed before detailed dredging design and permitting begins. The main work elements of the dredging feasibility study should include the following:

1. Attend a pre-application meeting with the DEP to discuss the project, to determine what permits will be required for this specific project, and to discuss potential disposal areas. A pre-application meeting is required by the DEP for dredging projects.

2. Identify a suitable disposal area for the contaminated sediments. Suitable areas may include non-residential properties, including County property or hazardous waste landfills.

3. Prepare a dredging feasibility report for submission to the County. Based on information provided in this report, Union County can determine if dredging Lower Echo Lake is feasible.

4. Include an evaluation of beneficial soil reuse and reclamation of the contaminated sediments.

6.1.2 Lake Aeration

Aeration has been widely used as a restoration measure for lakes where summer hypolimnetic oxygen depletion and/or winter-kill are of major concern. Aeration can be divided into two categories: those methods which destratify the lake water column and circulate the entire lake, and those methods which aerate the hypolimnion (deep water layer) without destratifying the lake. Both methods are based on the principle that if the dissolved oxygen concentration in a lake is increased, it will provide additional habitat for fish while decreasing the release of phosphorus from the sediments that can occur under anoxic (low dissolved oxygen) conditions.

Lower Echo Lake has low dissolved oxygen concentrations in both the bottom and surface waters of the lake. A destratification aeration system would keep all the water aerated and cause the water column to circulate. This type of aeration system is appropriate for Lower Echo Lake; however, it is not recommended at this time. Lake aeration should only be considered after dredging occurs and only if dissolved oxygen depletion of the bottom waters is still a problem.

6.1.3 Batch Alum Treatment (Phosphorus Inactivation)

Alum treatment involves adding aluminum sulfate (alum) to the water column. This process is also referred to as phosphorus inactivation. Alum treatment is most applicable to shallow lakes such as Lower Echo Lake.

Phosphorus inactivation through the application of chemicals to the water column or directly to the sediments can mitigate the release of phosphorus under anoxic conditions. A number of salts have been used in lakes, including aluminum, calcium and iron. The application of aluminum salts has been the most effective method, particularly in regard to long-term effectiveness. Alum (aluminum sulfate) is the most prevalent form of aluminum used in sediment phosphorus inactivation treatments.

Alum controls the release of phosphorus from sediments through the formation of aluminum hydroxide ($Al(OH)_3$) floc. Aluminum hydroxide forms complexes, chelates and insoluble precipitates with phosphorus. These aluminum complexes and polymers are inert to redox changes in the sediments and effectively trap and remove inorganic and particulate phosphorus from the water column.

Prior to recommending the use of alum treatment for Lower Echo Lake, special jar testing of the lake water is required to determine dosages and to evaluate the impact of the alum on the pH of the lake water. The cost for the additional testing and evaluation would be approximately $8,000. Implementation cost would be dependent upon dosage, but would be relatively inexpensive due to the size of the lake.

6.1.4 Algicide and Herbicide Treatment

Algicide and herbicide treatment is often used as a band-aid approach to control undesirable algae and macrophyte growth in a lake. Chemical algicides are costly, must be continuously added to the lake, and can cause a buildup of undesirable chemical compounds in the lake. Alternative long-term methods of improving water quality (i.e. dredging, nonpoint source pollution BMPs, shoreline stabilization) are environmentally responsible ways to avoid the use of potentially harmful chemicals.

6.1.5 Fish Stocking

A survey of fish species diversity should be performed approximately two years after the lake and watershed management recommendations have been implemented. Determining the number of fish and the different species present is critical to the development of a fish stocking program in order to ensure the best survival rate of the introduced fish. Once this information is determined, the lake should be stocked with the appropriate types and numbers of fish based on the lake size and the lake water quality.

6.2 Watershed Controls

6.2.1 Establish Existing Conditions - Watershed Investigations

As part of this study, limited watershed investigations were conducted to identify nonpoint source pollution problem areas. General types of problems in the watershed were identified as well as streambank and shoreline erosion problem areas. A more detailed watershed inventory should be performed to identify specific problem areas throughout the Lower Echo Lake watershed.

Since much of the watershed is already developed and since it was developed without the benefit of a comprehensive management plan, there are many existing areas that contribute to excessive stormwater runoff and soil erosion. These problem areas should be identified and prioritized so that retrofit efforts can be applied to correct the problems.

Areas to be investigated include, but should not be limited to, streambanks, culverts, roadways, roadway stream crossings, storm drainage pipes, and parking lots. Areas of excessive stormwater runoff and soil erosion should be investigated for all existing land uses including commercial, industrial, public, residential, and institutional.

Once these nonpoint source problem areas have been identified, they should be prioritized and analyzed for possible retrofit opportunities. Examples of potential retrofit opportunities include (Schueler, 1995):

1. Retrofit existing older stormwater management facilities.
2. Construct new stormwater controls at upstream end of road culverts.
3. Construct new stormwater controls at storm drainage pipe outfalls.
4. Construct on-site measures at the edges of large parking areas.
5. Construct new stormwater controls within highway rights-of-way.

Retrofit controls, or best management practices (BMPs) can include a large variety of measures including small detention areas, wet ponds, constructed wetlands, small pocket wetlands, sand filters, peat filters and bioretention systems. In some cases, retrofitting can consist of simple measures such as erosion control, soil stabilization, or stormwater diversion. Some nonpoint source problems can be eliminated by changing existing maintenance and operational procedures. For example, fertilization of lawns and golf courses could be modified to reduce nutrient runoff. Mowing of public areas could be modified to develop denser, taller, more natural vegetation, resulting in better control of stormwater runoff and increased removal of nutrients.

According to Thomas Schueler, Director of the Center for Watershed Protection (1995), elements to consider in stormwater retrofitting include the following:

! Ensure that retrofit site has adequate construction and maintenance access and sufficient construction staging area

- Verify existing utility locations, assess likelihood for conflicts, avoidance or relocation potential

- Identify existing natural resources and estimate sensitivity, avoid and minimize impacts where possible, assess likelihood for conflicts, and permit acquisition complications

- Identify adjacent land uses; select BMPs which will be compatible with nearby properties

- Assess the difficulty of obtaining permits and identify necessary agencies to contact.

- Define project purposes (i.e., is the retrofit intended to help stabilize the hydrologic regime in terms of quantity controls or is the retrofit more directed at pollutant removal in terms of quality controls?)

The watershed investigations should be coordinated by Union County. The prioritization of nonpoint source problem areas and the evaluation of retrofit opportunities, should be the ultimate goal of these activities.

6.2.2 Shoreline Stabilization

Soil erosion occurring along steep slopes, streambanks, and lake shoreline areas can contribute large quantities of nutrient-laden sediments to lakes. Land areas exhibiting high levels of soil erosion are commonly referred to as critical areas. Generally, soil erosion from critical areas will continue to occur at accelerated rates until these areas are properly stabilized. Excessive loadings of nutrient-laden sediments to lakes will result in increased levels of lake eutrophication.

Critical areas in a watershed may be stabilized using conventional methods, bioengineering methods, or a combination of both. Conventional methods such as rip-rap and gabions are very effective in controlling soil erosion, but they can be expensive to implement and do not always fit into the natural environment. Bioengineering methods consist of planted vegetation used separately or in conjunction with conventional methods to control soil erosion. Some highly effective bioengineering methods are live stakes, live fascine, brush layering, branchpacking, live gully repair, live cribwalls, vegetated rock gabions, vegetated rock walls, and vegetated rip-rap.

Most of the shoreline of Lower Echo Lake is stabilized with vegetation. Approximately 90 percent of the shoreline is lines with deciduous trees that provide protection against erosion and shading of the littoral zone of the lake. In general, a good forested buffer is provided around the lake. A 150 foot section of shoreline on the southern side of the lake is severely eroded (due to Hurricane Floyd) and should be stabilized with vegetative and structural measures. Several trees blew over into the lake during the hurricane taking big chunks of soil with them. The scarred area left behind is now highly erodible.

6.2.3 Streambank Stabilization

Nomahegan Creek and an unnamed tributary drain into Upper Echo Lake. Upper Echo Lake drains to Middle Echo Lake and then directly to Lower Echo Lake. These two tributary streams have eroding banks that should be stabilized. Union County is currently in the process of designing stabilization measures for these areas. Information regarding these streambank problems is provided in the Upper Echo Lake Watershed Management Plan. The streambank below the Lower Echo Lake dam has recently eroded as a result of Hurricane Floyd. Although this streambank is below the lake and does not affect the water quality of the lake, it should be stabilized to prevent continued erosion and downstream water quality problems.

6.2.4 Waterfowl Control

Canada geese populations at Lower Echo Lake are excessive and should be controlled. Geese droppings are a significant and direct source of phosphorus, nitrogen and bacteria to Lower Echo Lake. If necessary, geese populations can be controlled using a variety of methods including landscaping, egg inactivation, chemical deterrents, scare tactics, culling during summer molt, and geese removal. Park visitors should be discouraged from feeding the geese and other waterfowl. Signs should be posted at strategic locations in the park to inform people about not feeding the waterfowl. An ordinance prohibiting feeding and subsequent enforcement is recommended.

A few facts that are important to note regarding the resident Canada geese population at the park include:

1. Their life expectancy is very long in comparison to most bird species.
2. The move-in rate by new members of the population is not well documented; however, it is believed to be quite high.
3. There are few natural predatory species for the geese. The populations of the predatory species which do exist have been virtually eliminated in many areas due to intense urban development.
4. Hunting is nearly impossible due to intense urban development, and so it longer serves as a population check for the geese.

There are two basic solutions to the problem: on-site management techniques and removal of the geese from the site. These two solutions may be integrated to form a more effective geese control management plan.

Removal is a guaranteed option for eliminating the geese population. Removal is most easily conducted during molting when the geese are unable to fly and may be driven to a specified fenced-in area for capture. A major problem in removal and relocation of geese is that there are very few areas left to take the geese, since their presence is so undesirable. Presently, any geese captured under permit in Union County are destroyed and their edible parts are donated to local food banks.

On-site management of the geese is the other basic option for controlling the populations of resident Canada geese at a given location. Several on-site management techniques have been developed, tested, and found successful by the USDA, and are described below.

Controlled Landscaping Practices
Controlled landscaping practices and physical barriers will help deter the geese from residing in many areas. Studies have found that the geese do not feed in areas where the grass has been allowed to grow naturally. Also, preventing easy access to and from bodies of water greatly reduces the number of escape routes for the geese and therefore significantly decreases their level of security. This may be accomplished by allowing emergent wetland plants and shoreline vegetation such as shrubs and grasses to grow, or by erecting physical barriers such as snow fences. It is important to note that the use of controlled landscaping practices and physical barriers may not be acceptable for certain land uses where open space and access to waterbodies is essential or desirable.

Egg Inactivation
Egg inactivation has been successful in preventing the addition of new, young Canada geese into the local population. Geese are capable of laying eggs for an approximated 28 days. However, the gestation period is greater than 28 days. Therefore, by the time that the female realizes that the eggs will never hatch, she is no longer capable of producing another clutch during that season. The eggs may be inactivated by several methods, including shaking, puncturing, replacing eggs with plastic substitutes, or coating the eggs with oil. The eggs must appear to be intact so that the female will not realize their impotency and lay more eggs.

Visual Deterrents
Visual deterrents such as special filaments, balloons, and scarecrows may be useful in many areas where the geese like to congregate. The disadvantage of visual deterrents is that in many cases they are unsightly to humans, they are not acceptable in every land use, and they may lose their effectiveness as the geese become conditioned to their presence.

Chemical Deterrents
Chemical deterrents have also been developed by certain companies. These chemicals are applied directly to the vegetation in the areas where the geese feed and congregate, causing the geese to feel either discomfort or nausea. The use of certain visual deterrents (i.e. paint) in conjunction with the chemical deterrents may condition the geese to associate the visual deterrent with the discomfort or nausea. Therefore, over time, only the visual deterrent may be

necessary to control the geese and the use of chemical deterrents may either be reduced or eliminated. The disadvantages of this method are that the chemical deterrent must be applied many times during the season, and it is very expensive.

Scare Tactics
Scare tactics such as trained dogs manually chasing geese from areas of congregation, and explosive charges and other loud devices may be effective in driving the geese from a given area. Such methods may not be appropriate or safe, depending on the surrounding land use. And in many cases, the geese may become conditioned to and very tolerant of these scare tactics.

6.2.5 Urban Stormwater Management

Over the past ten years, a number of stormwater best management practices have been developed to reduce the adverse water quality impacts associated with urbanization. Overall, stormwater control measures serve two distinct functions: (1) to reproduce pre-development hydrologic conditions, and (2) to provide pollutant removal capabilities. Historically, stormwater management has focused on reducing the frequency and severity of downstream flooding by reducing the peak discharge from post-developed sites. More recently, stormwater management has been redefined to include the removal of pollutants, thereby improving and protecting the quality of downstream waters.

Below is a list of stormwater management practices that were evaluated for urban areas in the Lower Echo Lake watershed area. In developed areas, stormwater management should primarily focus on urban stormwater controls such as sand filters, water quality inlets, and infiltration structures. These stormwater controls do not require vast areas of land, and therefore can be integrated into existing urban settings.

Urban Stormwater Controls

1. Sand Filters
2. Water Quality Inlets
3. Infiltration Trenches
4. Bioretention Systems
5. Buffer Strips (Filter Strips)

In areas of future development or redevelopment, stormwater management controls such as infiltration basins, extended detention basins, constructed wetlands, and buffer strips should be constructed or implemented. These stormwater control measures typically require larger tracts of land and therefore should be incorporated or designed as part of the land development planning process.

Other options for improving the water quality of stormwater runoff include:

1. Union County and local municipalities should evaluate street sweeping schedules. Increased street sweeping is recommended, especially in the spring and summer months.

2. Stormwater catch basins should be cleaned after major storm events or at least once every three months. Cooperation between Union County and the local municipalities is recommended for this task.

3. Although most of the watershed is developed, every opportunity to improve stormwater quality should be taken. For example, if a commercial establishment changes ownership, and the new owner needs approvals from the local municipalities, local ordinances should be in place to require improving stormwater runoff quality from the site before approvals are granted. Possible stormwater quality treatment systems that could be installed on a developed property include sand filters, peat filters, or bioretention systems. The purpose of these systems is to treat the first 0.5 inches stormwater runoff from parking lots and roads, which is commonly called the "first flush."

4. Existing homeowners and business owners should be encouraged to direct roof runoff to dry pits or rain barrels to reduce the amount of stormwater that enters the storm sewer system. Using a rain barrel or cistern gives the homeowner the advantage of water use reduction by storing rain water for watering gardens or lawns during dry periods.

6.2.6 Homeowner Practices

Homeowner practices are important since most of the nutrients and sediments that enter Lower Echo Lake originate from residential land within the watershed. Several homeowner practices are listed below. These practices can be implemented as part of a public education program.

1. Lawn fertilizer can be a significant source of nutrients to lakes and ponds, especially in suburban areas where nice green lawns are desirable. A fact sheet on the importance of limiting lawn fertilization should be prepared and distributed to homeowners in the watershed. This task could be facilitated through the public education program described below or by an "extra" in the local newspaper. Fact sheets could be posted at the park and possibly at local businesses.

2. Leaf management is also important for reducing nonpoint source pollution in a developed watershed. The existing leaf management program should be evaluated to determine if there are ways to improve the program so that leaves do not end up in the street for a long period of time. If leaves are left in the street too long, nutrients leach from the leaves and are carried into the storm sewers and eventually into the lake with stormwater runoff. Encouraging or requiring homeowners to bag leaves in biodegradable bags is one possibility for improving the leaf management program.

3. Homeowners should be informed that if they dump household chemicals and other substances into storm sewers, these substances will end up in the lake. Storm drains should be stenciled to educate homeowners that anything that goes down the storm drain eventually drains directly into the lake.

4. Homeowners should be encouraged to wash cars and trucks on grassy areas, if possible, or use a commercial car wash. This practice will reduce the amount of phosphorus and detergent that runs down the driveway into a nearby storm sewer and eventually into Lower Echo Lake.

6.2.7 Riparian Corridor Restoration

Adequately vegetated or buffered streams remove pollutants from stormwater runoff. In addition to pollutant removal, stream buffers reduce water temperature, maintain stream flow during dry seasons, stabilize streambanks, decrease erosion potential, provide valuable wildlife habitat, provide improved in-stream aquatic habitat, provide flood control, and enhance the natural landscape by providing visually appealing "green belts."

Two tributaries enter Upper Echo Lake, which is upstream of Lower Echo Lake. A large portion of these tributaries are piped, underground systems. However, there are sections of the tributaries that are open, natural channels. These stream corridor areas should be preserved. Since these sections of the streams are located within Upper Echo Lake Park, Union County should maintain the stream corridors in their present condition. Eroded areas of the streambanks should be stabilized as described above, and a 50- to 75-foot buffer should be maintained along the entire stream channel. Willows and other trees should be planted along the smaller inlet stream.

A multi-zone buffer provides the best stream protection, including a zone of native trees next to the water's edge, a zone of shrubs and "disturbed forest" beyond that where recreational activities can occur, and a third zone composed of dense grasses, broad-leaved herbaceous plants, and wildflowers extending outward from the stream. A more extensive riparian buffer will have the additional benefit of reducing nuisance waterfowl congregation. The buffer should be maintained by replacing poor growing vegetation, removing invasive plant species, and protecting the area from game animals such as whitetail deer.

6.2.8 Golf Course Management

Several golf courses are located within the Lower Echo Lake watershed. Golf courses can be significant contributors to nonpoint source pollution in lakes and streams due to the excessive amounts of fertilizers sometimes used. However, with proper management, the amount of nutrients entering lakes and streams from golf courses can be kept to a minimum. Golf courses within the Lower Echo Lake watershed should be encouraged to minimize the use of fertilizers by turf monitoring and proper timing, water greens only when necessary as a means to reduce fertilizer usage, and implement stormwater management facilities such as constructed wetlands and bioretention strips to reduce fertilizer runoff into nearby water bodies. In addition, a three to five foot unmowed buffer strip along lakeshores and streambanks should be maintained to ensure proper erosion control and to filter runoff. Aesthetically pleasing vegetation such as irises and rushes can be planted in these areas.

The Audubon Cooperative Sanctuary Program provides golf course members and superintendents with information about environmentally-friendly golf course management. Program members become certified after developing a management program that incorporates fertilizer management practices, integrated pest management plans, vegetative buffer installation, habitat enhancement, stormwater management, and other techniques. Becoming involved with the Audubon Cooperative Sanctuary Program is an excellent way for a golf course to show the community its commitment to protecting the local environment.

6.2.9 Site Development Erosion and Sedimentation Pollution Control

Nonpoint source pollution from site development may be very significant during earthmoving and construction activities. The potential for soil erosion is very high until the site is stabilized with permanent vegetative cover, and is further heightened when soils are "highly erosive" and on steep slopes. Typically, large-scale development projects receive greater attention with respect to the installation and maintenance of proper erosion and sedimentation pollution controls. However, smaller construction projects such as single-family residential sites in many cases lack proper erosion and sedimentation pollution controls. In fact, at many small construction sites, no erosion and sedimentation pollution controls are implemented.

The Union County Soil Conservation District requires erosion and sedimentation pollution control plans for all earthmoving activities, large and small. Any disturbances greater than one acre require a National Pollution Discharge Elimination System permit from the New Jersey Department of Environmental Protection. Enforcement of erosion and sedimentation control at smaller sites is difficult due to the unsure timing of the actual earthmoving and the general lack of project information. However, erosion and sedimentation pollution control plans are just as important and should be enforced.

6.3 Public Education

The U.S. Environmental Protection Agency (EPA) actively encourages the development of environmental education programs by providing helpful literature, suggestions and funding sources. The U.S. EPA has funded education programs, such as the program developed for Lake Wallenpaupack (F. X. Browne, Inc., 1994), through its 314 Clean Lakes Program, its 319 Nonpoint Source Program and its Environmental Education Program.

Union County has developed and is continuing to implement an environmental education program throughout the County. The County's environmental education program should be integrated into the Lower Echo Lake watershed. The environmental education program for Lower Echo Lake should include the following elements:

1. Develop and distribute a nonpoint source brochure,
2. Develop a watershed management program for presentation to local schools,
3. Develop and install one or more kiosks at Lower Echo Lake Park,
4. Write fact sheet on watershed management for distribution at the kiosk and at park events, and
5.
6. Include staffing to conduct watershed management education programs at the satellite operation of Trailside Nature and Science Center being developed by the County in Warinanco Park.

6.4 Water Quality Monitoring Program

A limited water quality monitoring program should be implemented after dredging has been completed to document water quality improvements. Yearly monitoring of selected parameters (i.e. dissolved oxygen/temperature, total phosphorus, chlorophyll a, and Secchi disk transparency) should be conducted to document water quality changes in the lake. Sample collection could be tied into the Trailside curriculum mentioned above.

6.5 Institutional Practices

Union County Waterways Team

The Union County Waterways Team should work closely with Municipal officials to improve the water quality in Lower Echo Lake. Recommended tasks that should be performed by the Waterways Team with the assistance of Municipal officials are as follows:

1. Evaluate existing subdivision ordinances, erosion and sedimentation control ordinances, and other ordinances for their applicability to the Lower Echo Lake watershed area.

2. Determine if any of the above ordinances require revisions to further protect stream and lake water quality.

3. To assist in the coordination of all lake and watershed management activities.

4. Establish a “Watershed Watch” program to ensure that erosion and sedimentation controls are properly installed and maintained during and after construction activities and to watch for bank and stream erosion.

5. Communicate watershed problems including the lack of compliance with municipal and county-wide ordinances to the proper authorities.

6. Assist in obtaining funds for the implementation of lake and watershed management best management practices.

Ordinances

The Union County Waterways Team, with the assistance of municipal officials, should evaluate the existing erosion and sedimentation control and stormwater control ordinances to ensure that these documents are effectively protecting the water quality in County streams and lakes. The Waterways Team, with the assistance of municipal officials, should also evaluate the applicability of lawn fertilization and waterfowl feeding ordinances for the Lower Echo Lake watershed.

6.6 Implementation Costs

The proposed budget for the various elements of the Lower Echo Lake Restoration Project is shown in Table 6.1. These costs include engineering design, permitting, construction and construction observation costs. The cost for dredging Lower Echo Lake is difficult to estimate since the sediments are contaminated. However, assuming that an acceptable disposal area can be found within 5 miles of the lake, and assuming that capping or covering the sediment is required, the estimated cost to dredge Lower Echo Lake could range from $985,000 to $1,500,000. This cost may increase if the sediment must be disposed of in a hazardous waste landfill. .

6.7 Funding Sources

There are several state and federal programs that provide funding for lake and watershed management projects. The two primary funding sources for implementing the recommended management plan are the New Jersey Clean Lakes Program and the EPA's 319 Nonpoint Source Program. The 319 Nonpoint Source program provides funds for watershed management projects and public education programs. Union County has already received and is implementing a 319 grant to install streambank and shoreline stabilization measures and enhance their environmental education program for Upper Echo Lake.

6.8 Lower Echo Lake Restoration Project Schedule

The recommended management plan for Lower Echo Lake should be implemented in stages. In particular, watershed best management practices should be first implemented in the most critical areas. The dredging feasibility study can begin immediately so that a suitable sediment disposal area can be found as soon as possible. After watershed practices are installed and after the dredging feasibility study is complete, dredging design, permitting and construction can begin.

Table 6.1
Budget Summary for the Proposed
Lower Echo Lake Restoration Project

Task	Description	Estimated Capital Costs*	Estimated Annual Costs
1	Dredging Feasibility Study (including soil testing)	$22,000	$0
2	Detailed Dredging Design, Permitting and Construction**	$1,800,000	$0
3	Batch Alum Treatment Feasibility Study	$12,000	$0
4	Shoreline Stabilization	$85,000	$0
5	Streambank Stabilization	$70,000	$0
6	Homeowner Practices	$7,000	$1,000
8	Environmental Education	$11,000	$2,000
9	Water Quality Monitoring	$5,000	$5,000
5	Evaluate Stormwater Runoff Retrofit Possibilities in the Watershed	$13,000	$0
6	Stormwater Runoff Control Measures	$25,000	$25,000
Total		**$2,053,000**	**$33,000**

* These costs are in 2003 dollars and are subject to change based on when and to what extent the management program is implemented.

** The construction cost for lake dredging is estimated at $985,000 - $1,500,000 as described in Section 6.4.

7.0 Environmental Evaluation

Since socio-economic and environmental impacts are part of the cost-effectiveness analysis for the restoration of Lower Echo Lake, many of these impacts were addressed during the evaluation of restoration alternatives. However, the impacts and their mitigative measures are formally documented below using the environmental evaluation checklist in the Clean Lakes Program Guidance Manual (U.S. EPA, 1980).

1. Will the project displace people?

   No.

2. Will the project deface existing residences or residential areas?

   No. Residential areas are not affected by the proposed plan.

3. Will the project be likely to lead to changes in established land use pattern or an increase in development pressure?

   No.

4. Will the project adversely affect prime agricultural land or activities?

   No.

5. Will the project adversely affect parkland, public land or scenic land?

   Temporarily. During the lake sediment removal and shoreline stabilization portions of this project, sections of the parkland will be disturbed. Upon completion of lake dredging, the parkland will be regraded and revegetated to its original appearance.

6. Will the project adversely affect lands or structures of historic, architectural, archeological or cultural value?

   No.

7. Will the project lead to a significant long-range increase in energy demands?

   No.

8. Will the project adversely affect short-term or long-term ambient air quality?

   No.

9. Will the project adversely affect short-term or long-term noise levels?

   No.

10. If the project involves the use of in-lake chemical treatment, will it cause any short-term or long-term effects?

    No chemical treatments are proposed for Lower Echo Lake as outlined in the Lake and Watershed Management Plan Section of this report.

11. Will the project be located in a floodplain?

    Yes. Sediment removal activities will be temporarily employed in Lower Echo Lake.

12. Will structures be constructed in the floodplain?

    Yes..

13. If the project involves physically modifying the lake shore, its bed, or its watershed, will the project cause any short or long-term adverse effects?

    Yes. A portion of lake shoreline will be regraded and revegetated to reduce further soil erosion; however no adverse effects are expected. The short-term adverse effect of the construction work required for the regrading of the shoreline will be minimal, and after a few months, the vegetation will be established.

14. Will the project have a significant adverse effect on fish and wildlife, wetlands or other wildlife habitat?

    Yes. Sediment removal will have short-term adverse impacts on the aquatic biota. However, within six months after dredging is complete, the benthic community is expected to return to normal.

15. Have all feasible alternatives to the project been considered in terms of environmental impacts, resource commitment, public interest and cost?

    Yes.

16. Are there other measures not previously discussed which are necessary to mitigate adverse impacts resulting from the project?

    There are no possible mitigation measures known at the present time which have not been discussed.

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APPENDIX A

GLOSSARY OF LAKE AND WATERSHED MANAGEMENT TERMS

Glossary of Lake and Watershed Terms

Acid neutralizing capacity (ANC): the equivalent capacity of a solution to neutralize strong acids. The components of ANC include weak bases (carbonate species, dissociated organic acids, alumino-hydroxides, borates, and silicates) and strong bases (primarily, OH-). In the National Surface Water Survey, as well as in most other recent studies of acid-base chemistry of surface waters, ANC was measured by the Gran titration procedure.

Acidic deposition: transfer of acids and acidifying compounds from the atmosphere to terrestrial and aquatic environments via rain, snow, sleet, hail, cloud droplets, particles, and gas exchange.

Adsorption: The adhesion of one substance to the surface of another: clays, for example, can adsorb phosphorus and organic molecules

Aerobic: Describes life or processes that require the presence of molecular oxygen.

Algae: Small aquatic plants that occur as single cells, colonies, or filaments. Planktonic algae float freely in the open water. Filamentous algae form long threads and are often seen as mats on the surface in shallow areas of the lake.

Alkalinity: (see *acid neutralizing capacity*).

Allochthonous: Materials (e.g., organic matter and sediment) that enter a lake from atmosphere or drainage basin (see *autochthonous*).

Anaerobic: Describes processes that occur in the absence of molecular oxygen.

Anoxia: A condition of no oxygen in the water. Often occurs near the bottom of fertile stratified lakes in the summer and under ice in late winter.

Anoxic: "Without oxygen." (see *anoxia*).

Autochthonous: Materials produced within a lake e.g., autochthonous organic matter from plankton versus allochthonous organic matter from terrestrial vegetation.

Bathymetric map: A map showing the bottom contours and depth of a lake; can be used to calculate lake volume.

Benthic: Macroscopic (seen without aid of a microscope) organisms living in and on the bottom sediments of lakes and streams. Originally, the term meant the lake bottom, but it is now applied almost uniformly to the animals associated with the substrate. Also referred to as *benthos*.

Biochemical oxygen demand (BOD): The rate of oxygen consumption by organisms during the decomposition (respiration) of organic matter, expressed as grams oxygen per cubic meter of water per hour.

Biomass: The weight of biological matter. Standing crop is the amount of biomass (e.g., fish or algae) in a body of water at a given time. Often measured in terms of grams per square meter of surface.

Biota: All plant and animal species occurring in a specified area.

Chemical oxygen demand (COD): Non-biological uptake of molecular oxygen by organic and inorganic compounds in water.

Chlorophyll: A green pigment in algae and other green plants that is essential for the conversion of sunlight, carbon dioxide and water to sugar (photosynthesis). Sugar is then converted to starch, proteins, fats and other organic molecules.

Chlorophyll a: A type of chlorophyll present in all types of algae, sometimes in direct proportion to the biomass of algae.

Cluster development: Placement of housing and other buildings of a development in groups to provide larger areas of open space

Consumers: Animals that cannot produce their own food through photosynthesis and must consume plants or animals for energy (see *producers*).

Decomposition: The transformation of organic molecules (e.g., sugar) to inorganic molecules (e.g., carbon dioxide and water) through biological and non-biological processes.

Delphi: A technique that solicits potential solutions to a problem situation from a group of experts and then asks the experts to rank the full list of alternatives.

Density flows: A flow of water of one density (determined by temperature or salinity) over or under water of another density (e.g. flow of cold river water under warm reservoir surface water).

Detritus: Non-living dissolved and particulate organic material from the metabolic activities and deaths of terrestrial and aquatic organisms.

Drainage basin: Land area from which water flows into a stream or lake (see *watershed*).

Drainage lakes: Lakes having a defined surface inlet and outlet.

Ecology: Scientific study of relationships between organisms and their environment: also defined as the study of the structure and function of nature.

Ecosystem: A system of interrelated organisms and their physical-chemical environment. In limnology, the ecosystem is usually considered to include the lake and its watershed.

Effluent: Liquid wastes from sewage treatment, septic systems or industrial sources that are released to a surface water.

Environment: Collectively, the surrounding conditions, influences and living and inert matter that affect a particular organism or biological community.

Epilimnion: Uppermost, warmest, well-mixed layer of a lake during summertime thermal stratification. The epilimnion extends from the surface to the thermocline.

Erosion: Breakdown and movement of land surface which is often intensified by human disturbances.

Eutrophic: From Greek for well-nourished; describes a lake of high photosynthetic activity and low transparency.

Eutrophication: The process of physical, chemical, and biological changes associated with nutrients, organic matter, silt enrichment, and sedimentation of a lake or reservoir. If the process is accelerated by man-made influences it is termed cultural eutrophication.

Fall overturn: The autumn mixing, top to bottom, of lake water caused by cooling and wind-derived energy.

Fecal coliform test: Most common test for the presence of fecal material from warm-blooded animals. Fecal coliforms are measured because of convenience; they are not necessarily harmful but indicate the potential presence of other disease-causing organisms.

Floodplain: Land adjacent to lakes or rivers that is covered as water levels rise and overflow the normal water channels.

Flushing rate: The rate at which water enters and leaves a lake relative to lake volume, usually expressed as time needed to replace the lake volume with inflowing water.

Flux: The rate at which a measurable amount of a material flows past a designated point in a given amount of time.

Food chain: The general progression of feeding levels from primary producers, to herbivores, to planktivores, to the larger predators.

Food web: The complex of feeding interactions existing among the lake's organisms.

Forage fish: Fish, including a variety of panfish and minnows, that are prey for game fish.

Groundwater: Water found beneath the soil surface; saturates the stratum at which it is located; often connected to lakes.

Hard water: Water with relatively high levels of dissolved minerals such as calcium, iron, and magnesium.

Hydrographic map: A map showing the location of areas or objects within a lake.

Hydrologic cycle: The circular flow or cycling of water from the atmosphere to the earth (precipitation) and back to the atmosphere (evaporation and plant transpiration). Runoff, surface water, groundwater, and water infiltrated in soils are all part of the hydrologic cycle.

Hypolimnion: Lower, cooler layer of a lake during summertime thermal stratification.

Hypoxia: A condition of low oxygen in the water (< 2.0 mg/L). Often occurs near the bottom of fertile stratified lakes in the summer and under ice in late winter.

Influent: A tributary stream.

Internal nutrient cycling: Transformation of nutrients such as nitrogen or phosphorus from biological to inorganic forms through decomposition, occurring within the lake itself. Also refers to the release of sediment-bound nutrients into the overlying water that typically occurs within the anoxic hypolimnion of stratified, mesotrophic and eutrophic lakes.

Isothermal: The same temperature throughout the water column of a lake.

Lake: A considerable inland body of standing water, either naturally formed or manmade.

Lake district: A special purpose unit of government with authority to manage a lake(s) and with financial powers to raise funds through mill levy, user charge, special assessment, bonding, and borrowing. May or may not have police power to inspect septic systems, regulate surface water use, or zone land.

Lake management: The practice of keeping lake quality in a state such that attainable uses can be achieved and maintained.

Lake protection: The act of preventing degradation or deterioration of attainable lake uses.

Lake restoration: The act of bringing a lake back to its attainable uses.

Lentic: Relating to standing water (versus lotic, running water).

Limnologist: One who studies limnology.

Limnology: Scientific study of fresh water, especially the history, geology, biology, physics, and chemistry of lakes. Also termed freshwater ecology.

Littoral zone: That portion of a waterbody extending from the shoreline lakeward to the greatest depth occupied by rooted plants.

Loading: The total amount of material (sediment, nutrients, oxygen-demanding material) brought into the lake by inflowing streams, runoff, direct discharge through pipes, groundwater, the air, and other sources over a specific period of time (often annually).

Macroinvertebrates: Aquatic insects, worms, clams, snails, and other animals visible without the aid of a microscope, that may be associated with or live on substrates such as sediments and macrophytes. They supply a major portion of fish diets and consume detritus and algae.

Macrophytes: Rooted and floating aquatic plants, commonly referred to as waterweeds. These plants may flower and bear seed. Some forms, such as duckweed and coontail (*Ceratophyllum*), are free-floating forms without roots in the sediment.

Mandatory property owners association: Organization of property owners in a subdivision or development with membership and annual fee required by covenants on the property deed. The association will often enforce deed restrictions on members' property and may have common facilities such as bathhouse, clubhouse, golf course, etc.

Marginal zone: Area where land and water meet at the perimeter of a lake. Includes plant species, insects and animals that thrive in this narrow, specialized ecological system.

Mesotrophic: Describes a lake of moderate plant productivity and transparency; a trophic state between oligotrophic and eutrophic.

Metalimnion: Layer of rapid temperature and density change in a thermally stratified lake. Resistance to mixing is high in this region.

Morphometry: Relating to a lake's physical structure (e.g., depth, shoreline length).

Nekton: Large aquatic organisms whose mobility is not determined by water movement -- for example, fish and amphibians.

Nominal group process: A process of soliciting concerns/issues/ideas from members of a group and ranking the resulting list to ascertain group priorities. Designed to neutralize dominant personalities.

Nutrient: An element or chemical essential to life, such as carbon, oxygen, nitrogen, and phosphorus.

Nutrient budget: Quantitative assessment of nutrients (e.g., nitrogen or phosphorus) moving into, being retained in, and moving out of an ecosystem; commonly constructed for phosphorus because of its tendency to control lake trophic state.

Nutrient cycling: The flow of nutrients from one component of an ecosystem to another, as when macrophytes die and release nutrients that become available to algae (organic to inorganic phase and return).

Oligotrophic: "Poorly nourished," from the Greek. Describes a lake of low plant productivity and high transparency.

Ooze: Lake bottom accumulation of inorganic sediments and the partially decomposed remains of algae, weeds, fish, and aquatic insects. Sometimes called muck (see *sediment*).

Ordinary high water mark: Physical demarcation line, indicating the highest point that water level reaches and maintains for some time. Line is visible on rocks, or shoreline, and by the location of certain types of vegetation.

Organic matter: Molecules manufactured by plants and animals and containing linked carbon atoms and elements such as hydrogen, oxygen, nitrogen, sulfur, and phosphorus.

Paleolimnology: The study of the fossil record within lake sediments.

Pathogen: A microorganism capable of producing disease. They are of great concern to human health relative to drinking water and swimming beaches.

Pelagic zone: This is the open area of a lake, from the edge of the littoral zone to the center of the lake.

Perched: A condition where the lake water is isolated from the groundwater table by impermeable material such as clay.

pH: A measure of the concentration of hydrogen ions of a substance, which ranges from very acid (pH = 1) to very alkaline (pH = 14). pH 7 is neutral and most lake waters range between 6 and 9. pH values less than 6 are considered acidic, and most life forms can not survive at pH of 4.0 or lower.

Photic zone: The lighted region of a lake where photosynthesis takes place. Extends down to a depth where plant growth and respiration are balanced by the amount of light available.

Phytoplankton: Microscopic algae and microbes that float freely in open water of lakes and oceans.

Plankton: Microscopic plants, microbes and animals floating or swimmng freely about in lakes and oceans.

Primary productivity: The rate at which algae and macrophytes fix or convert light, water and carbon dioxide to sugar in plant cells (through photosynthesis). Commonly measured as milligrams of carbon per square meter per hour.

Primary producers: Green plants that manufacture their own food through photosynthesis.

Profundal zone: Area of lake water and sediment occurring on the lake bottom below the depth of light penetration.

Reservoir: A manmade lake where water is collected and kept in quantity for a variety of uses, including flood control, water supply, recreation and hydroelectric power.

Residence time: Commonly called the hydraulic residence time -- the amount of time required to completely replace the lake's current volume of water with an equal volume of new water.

Respiration: Process by which organic matter is oxidized by organisms, including plants, animals, and bacteria. The process releases energy, carbon dioxide, and water.

Secchi depth: A measure of transparency of water obtained by lowering a black and white, or all white, disk (Secchi disk, 20 cm in diameter) into water until it is no longer visible. Measured in units of meters or feet.

Sediment: Bottom material in a lake that has been deposited after the formation of a lake basin. It originates from remains of aquatic organisms, chemical precipitation of dissolved minerals, and erosion of surrounding lands (see *ooze* and *detritus*).

Seepage lakes: Lakes having either an inlet or outlet (but not both) and generally obtaining their water from groundwater and rain or snow.

Soil retention capacity: The ability of a given soil type to adsorb substances such as phosphorus, thus retarding their movement to the water.

Stratification: Layering of water caused by differences in water density. Thermal stratification is typical of most deep lakes during summer. Chemical stratification can also occur.

Swimmers itch: A rash caused by penetration into the skin of the immature stage (cercaria) of a flatworm (not easily controlled due to complex life cycle). A shower or alcohol rubdown should minimize penetration.

Thermal stratification: Lake stratification caused by temperature-created differences in water density.

Thermocline: A horizontal plane across a lake at the depth of the most rapid vertical change in temperature and density in a stratified lake (see *metalimnion*.).

Topographic map: A map showing the elevation of the landscape at specified contour intervals (typically 10 or 20 foot intervals, may be expressed in feet or meters). Can be used to delineate the watershed.

Trophic state: The degree of eutrophication of a lake. Transparency, chlorophyll a levels, phosphorus concentrations, amount of macrophytes, and quantity of dissolved oxygen in the hypolimnion can be used to assess state.

Voluntary lake property owners association: Organization of property owners in an area around a lake that members join at their option.

Water column: Water in the lake between the interface with the atmosphere at the surface and the interface with the sediment layer at the bottom. Idea derives from vertical series of measurements (oxygen, temperature, phosphorus) used to characterize lake water.

Water table: The upper surface of groundwater; below this point, the soil is saturated with water.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Zooplankton: Microscopic animals that float or swim freely in lake water, graze on detritus particles, bacteria, and algae, and may be consumed by fish.

APPENDIX B

LOWER ECHO LAKE WATER QUALITY DATA

APPENDIX C

LOWER ECHO LAKE SEDIMENT RESULTS